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Generic Extravehicular (EVA) and Telerobot Task Primitives for Analysis, Design, and Integration

Version 1.0: Reference Compilation for the EVA and Telerobotics Communities

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ABSTRACT

This report describes the results of an effort to establish commonality and standardization of generic crew-extravehicular (crew-EVA) and telerobotic task analysis primitives used for the study of spaceborne operations. Although direct crew-EVA plans are the most visible output of spaceborne operations, significant ongoing efforts by a wide variety of projects and organizations also require tools for estimation of crew-EVA and telerobotic times. Task analysis tools provide estimates for input to technical and cost trade-off studies. A workshop was convened to identify the issues and needs of a nationwide task analysis community. Agreement was reached on the need to establish a common language and syntax for task analysis primitives. In addition, the importance of such a syntax was shown to have precedence over the level to which such a syntax is applied. The syntax, lists of crew-EVA and telerobot primitives, and the database in diskette form are presented. This report represents the collective efforts of numerous individuals and organizations.

FOREWORD

The Advanced Robotics for In-Space Vehicle Processing task was established to study and identify the implications of evolutionary robotics technologies for the baselined design of the Space Station *Freedom*. The objectives of the task are to identify hardware and software accommodations to the baseline design for vehicle processing that will facilitate later upgrades in technology.

The analysis of crew-EVA timelines highlighted the need for a software tool to facilitate the analysis of telerobotics technologies and manage the large quantities of related information. The Telerobotics/EVA Joint Analysis System (TEJAS) task was formed to meet that need. As output from the Advanced Robotics task was initially being used to construct the TEJAS database, it became apparent that widespread interest in the task analysis community provided an opportunity to share approaches and resolve some of the differences in definitions being used.

This report describes the results of a task analysis community effort to establish agreement on a uniform set of crew-EVA and telerobot primitives for the purposes of operations analysis. A wide array of ongoing studies, all with different definitions of tasks, activities, and primitives, are performing essentially similar task analysis functions. The results presented in this report are an attempt to establish uniformity in the generic task primitives for the purposes of improved communication, evaluation of assumptions, and estimation of operational requirements.

Although the present activity has emerged from a JPL effort, the content of this report is essentially the product of crew-EVA and robotics task analysis community inputs. The initial gathering of participants that led to this report met in the hope that a more in-depth understanding of task analysis practices through an informal, educational exchange of information might lead to ideas and guidelines for future task analyses. However, the meeting developed a broad interest and participation that led to a number of beneficial synergistic outcomes and agreements regarding content and syntax.

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This work could not have been completed without the involvement of many individuals in numerous organizations who gave generously of their time. The organizations and individuals are listed in Table i-1. The right-hand side of the table summarizes the role of each participant present at the task analysis workshop. The task analysis workshop initiated the process leading to this report. The details of the participation categories are described in the report.

A special thanks is owed to Fran Mulvehill, who patiently typed this manuscript. Notwithstanding the help of the individuals and organizations above, the responsibility for this report rests with the authors. General questions regarding the report should be directed to:

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Table i-1. Individual Acknowledgments of Workshop Involvement

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*(6/7/89 MDSSC = June 7th, 1989 meeting on Task Analysis and Primitives)

*(T&CETAA = Telerobotics & Crew EVA Task Analysis Approaches

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SECTION I

INTRODUCTION AND SUMMARY

A. REPORT ORGANIZATION

This report is divided into five sections. Section I provides a summary and introduces the purpose, objectives, and scope of this report. Section II describes the approach used in developing the task analysis workshop as well as its activities, results, and participation. Section III describes the results of the post-workshop analysis, which includes comments and generic primitives provided by the workshop participants. Section IV is a discussion of the issues raised, limitations, future needs, and conclusions. Section V presents the compilation of generic crew-EVA and telerobot primitives. Section VI contains a TEJAS User's Miniguide for the software database. References are listed in Section VII.

B. SUMMARY

This report contains standardized lists of generic crew-extravehicular (crew-EVA) and telerobotic task analysis primitives for the development of crew-EVA and telerobotic timelines. Such timelines are important to better understand the use of crew and telerobotic work systems. This report is a product of numerous organizations and individuals who met in a workshop atmosphere to exchange ideas on the theme of task analysis.

The following products and conclusions were drawn from this activity:

(1) The documentation of a version 1.0 reference compilation of crew-EVA generic task analysis primitives is intended for use in crew-EVA task planning and analysis. The list of generic primitives, sorted by action verbs, is contained in Section V-A. The verbs are listed in alphabetical order followed by the definition, syntax, like verbs, and antonym. The historical evolution of the list and syntax is presented in Appendix B for traceability purposes.

(2) The documentation of a version 1.0 reference compilation of telerobot generic task analysis primitives is intended for use in telerobot operations planning and analysis. The list of generic primitives, sorted by action verbs, is contained in Section V-B. The verbs are in alphabetical order followed by the definition, syntax, like verbs, and antonym. The historical evolution of the list and syntax is presented in Appendix C for traceability purposes.

(3) The version 1.0 software database containing the lists of generic primitives is included with this report for use, modification, or review by any interested party. Section VI describes this tool and its usage. A software tool for the purposes of managing the primitives lists and creating crew-EVA and telerobot timelines is included with this report. User feedback is requested in order to

evolve a standardized reference and revision procedures that have been built in to manage changes.

(4) The generic crew-EVA and telerobot primitives lists provide a language for communicating and analyzing in-space tasks for the purposes of better understanding effective and efficient roles for both crew and telerobots (Section IV).

(5) A task-specific primitive results from specification of the generic arguments of a generic primitive. Once specified, a set of task-specific primitives becomes a "script" for operation of the work system. While it is not possible to standardize task-specific primitives, it is feasible to standardize generic primitives and a syntax. This report documents a standard proposed by members of the task analysis community.

(6) Insights were obtained on how task analyses are currently being performed by a variety of organizations. Although the basic methods are similar, a key problem area is the lack of definitions and standardization. The confusion in terminology stems from a need for operational definitions. A description of the basic task analysis approach and suggested definitions is presented in Section III-A.

(7) The next step in the development of a tool for generating task-specific "scripts" from a set of generic task analysis primitives requires that existing databases of the support infrastructure be imported into the task analysis process (e.g., the "EVA Tools and Equipment Catalog"). Such databases contain the arguments for generic primitives that facilitate conversion of generic primitives to specific primitives for a specific task. It is recommended that the task analysis community, in conjunction with the appropriate standards committees, conduct such activities to translate these hard copy desk references to electronic media. It is also recommended that a second workshop be held to refine the existing standard and remaining requirements.

C. PURPOSE

The space telerobotics community has grown rapidly in recent years and, as telerobots are currently being designed to perform on-orbit tasks, broad interest has developed for understanding the components of improved selection and planning of crew- and telerobot-performed tasks. Space operations such as assembly, servicing, maintenance, and payload handling have been performed historically by crew-EVA and the first space telerobot, the Space Shuttle Remote Manipulator System (SSRMS).

With the advent of the Space Station *Freedom,* the potential workload demand for crew-EVA will increase the need for telerobot support. Consequently, the need for reliable, easy-to-use task analysis methodologies, tools, and techniques for the study of on-orbit operations is recognized by members of both the crew-EVA and telerobotics community. Each group

has reasoned that a complete understanding of the crew-EVA/telerobotics relationship is necessary to quantify and leverage the benefits and risks of developing enabling technologies. Many groups appear to be pursuing task analysis methodology development in a similar fashion on both sides of the human/machine boundary with unspecified plans on how to combine crew-EVA and telerobot work systems. This synthesis is more difficult than it appears and is complicated by an array of different definitions and terminologies.

The approach that both the crew-EVA and the telerobotics communities have used is to subdivide work activities into smaller generic components called "primitives." These primitives are used to compose larger work activities. The variety of organizations and groups independently pursuing the study of space operations has led to a proliferation of different definitions, assumptions, interpretations, and usages of primitives.

The purpose of this report is to document the results of an effort to establish commonality and standardization, to the extent possible between existing task analysis concepts as well as to develop a set of uniform generic crew-EVA and telerobot primitives for the task analysis community. The report establishes a common language to better understand the performance of crew-EVA and potential telerobots for in-space tasks.

The approach is based on the concept of action primitives and builds on the research of industrial, ground-based robotics (References 1 through 5). The approach is also derived from similar work in the robot planning area which generally leads to consideration of robot primitive actions (e.g., References 6, 7, 8).

JPL has been involved in a variety of task analysis studies for the purposes of analyzing the tasks, technologies, and trade-offs associated with automated and robotic systems (References 8 through 16). During related studies of advanced robotics for on-orbit vehicle processing (References 17 through 19), it became apparent that there is a range of task analysis interest among other members of the NASA telerobotics community performing similar crew-EVA and telerobotic studies (References 20 through 25). These contacts indicated a widespread desire in the community to establish a consensus regarding definitions and task analysis approaches. While the present study (Reference 25) was interacting with Code ST-sponsored efforts at the Kennedy Space Center (KSC) (Reference 26), broader coordination was needed. It was determined that if the task analysis community could agree on a common set of terms, definitions, and analytic "primitives" for both crew-EVA and telerobots, the overall utility of related products would benefit.

A number of members of this study network, notably persons at the Jet Propulsion Laboratory (JPL), KSC, Johnson Space Center (JSC), and Langley Research Center (LaRC), planned a meeting to review various studies being performed and to attempt to establish a common overall framework for these diverse activities. Because none of the study teams had programmed resources to cover such a meeting, the task analysis meeting was combined with another meeting that would bring most of the interested parties together. Such an opportunity occurred when the McDonnell-Douglas Space Systems Company (MDSSC) invited a broad cross section of the community to view a test/demonstration of

astronaut-robotic cooperation under simulated microgravity conditions in the neutral buoyancy facility at MDSSC, Huntington Beach, California, during the period June 6-8, 1989. An all-day working meeting to exchange information and ideas about analyzing crew and automation and robotic performance of on-orbit tasks was scheduled for June 7, 1989.

D. OBJECTIVES

A number of objectives were identified to address questions facing participants from the crew-EVA and telerobotics communities. The objectives of the study are

(1) To publish lists of standardized generic crew-EVA and telerobot primitives and a common syntax for these generic primitives.

(2) To distribute the generic crew-EVA and telerobot primitive lists to users and other interested parties for use and further feedback.

(3) To acknowledge the cooperative spirit and work of the community in this effort.

The publication of these lists establishes an unofficial "standard" agreed upon by the EVA task analysis community. It further demonstrates to the NASA community at large, the work, issues, and limitations involved in standardizing a language for EVA task analysis. The compilation presented in this report is a reference point from which to improve the enclosed definitions, syntaxes, and relationships. No claim is made that the enclosed generic primitives represent a final list.

The wider the distribution of these lists, the more feedback they are likely to produce. Such feedback is critical to the applicability of the generic primitives. With help from its users, this language can remain a valuable medium for communication within the community.

It should be stressed that this work is a community effort. The enthusiasm and cooperation of the community mirrors the importance of such work, while the variety of participants enhances the value and credibility of the work. It is necessary, therefore, to acknowledge these individuals, both for the sake of giving credit where credit is due and for traceability purposes.

E. SCOPE

The scope of the study is limited to consideration of crew-EVA and telerobot primitives. No consideration of intravehicular (IVA) primitives is provided in this version due to the lower costs of IVA, added complexities of identifying locus of control, and time allocation problems associated with IVA primitives. Initial study of IVA primitives has been initiated in the related area of on-orbit automation (Reference 26).

F. EXTRAVEHICULAR TASK REQUIREMENTS

Space Station *Freedom* (SSF) operations will involve large amounts of crew-EVA to perform a variety of tasks such as assembly, servicing, maintenance, and inspection. The requirements for housekeeping and servicing are typically stated in terms of budgeted crew-EVA hours for the tasks involved. Simply stated, EVA requirements are the "work" that needs to be performed to keep the spacecraft system in operational order and perform its mission(s). Task analysis seeks to optimize available EVA excursion time by planning in detail the subtasks to be performed. The individual steps in these subtasks are referred to as "crew-EVA primitives."

A decision facing crew operations managers is when and how to use telerobot work systems for performing required tasks. The requirements for EVA operations have been and will continue to be formulated in terms of crew-performed tasks; however, the requirements for telerobot operations will evolve with additional experiences and applications of telerobot technologies. A fundamental element of planning telerobot operations is compiling a language and syntax that describe the component activities of each task. Planning telerobot operations is similar to planning crew-EVA operations in that procedures composed of telerobot activities must be assembled at some level to execute the desired actions. The term used for these elementary activities is "telerobot primitives."

G. TRANSLATING TASK REQUIREMENTS INTO ACTION

Regardless of the task to be performed, a mechanism is needed to convert or translate the description and assumptions about each task into a plan of action. This plan of action is a script of <u>specific</u> primitives, which were derived from a <u>generic</u> primitives set (e.g., see Section V). Before proceeding further, it is appropriate to define precisely the terminology for two cases: (1) the crew-EVA, and (2) the telerobot case.

<u>Crew-Eva Case</u>

1. Primitive, crew-EVA (Generic): The smallest descriptive task component for a crewmember performing EVA, involving a subject (crew), an action VERB, and undefined arguments in a consistent syntax. Example Verbs: GRASP, TRANSLATE, MATE, VERIFY.

2. Primitive, crew-EVA (Specific): The smallest descriptive task component for a crewmember performing EVA, involving a subject (EV1, EV2, etc.), an action VERB, the object of that action, and external factors, all defined as specific arguments connected by prepositions, and evolving from generic primitives. Examples: EV1 GRASP wrench, EV2 TRANSLATE to MMU, EV1 ATTACH tether to slidewire, EV2 VERIFY clear of obstructions.

<u>Telerobotics Case</u>

1. Primitive, Telerobot (Generic): The smallest descriptive task component possible above actual coding of computer instructions

(commands) to the telerobot, involving a subject, an action VERB, and undefined arguments in a consistent syntax. Example Verbs: GRASP, MOVE, STOP, ACQUIRE.

2. Primitive, Telerobot (Specific): The smallest descriptive task component possible above actual coding of computer instructions (commands) to the telerobot, involving a subject (a system or subsystem, including an operator if teleoperating), an action VERB, the object(s) of that action, and external factors, all defined as specific arguments connected by prepositions, and evolving from generic primitives. Examples: FTS GRASP ORU with gripper1; RMS MOVE PFA 0.3m +X; IV1 STOP SSRMS; vision subsystem ACQUIRE vertex A.

Because there is no clear interrelationship between how crew-EVA and a telerobot perform parts of the same task, it is customary to consider a task as entirely crew-EVA or entirely telerobotic.

The crew-EVA case is illustrated in Figure 1-1 and involves the task description and outline (the task summary), the assumptions about task sequencing, the worksite, tools, and resources used in cooperation with the generic crew-EVA primitives to create a list of specific crew-EVA primitives approximating the task (similar to the task outline and resembling a crew-EVA checklist). The specific primitives enable the construction of a specific crew-EVA timeline for use in crew training and task optimization. Generic crew-EVA primitives therefore should be defined so that any task or subtask can be synthesized from such a generic list. The methodology followed can vary. Multiple levels of specification are compatible if the specific primitives on each level are generated using the same assumptions and the same generic primitives list.

The telerobotic case is similar. Again, the task description and outline, the assumptions about task sequencing, the worksite, tools, and resources required are used in cooperation with the generic telerobot primitives to create a list of specific telerobot primitives approximating the outline for the task. However, there are no prior "telerobot checklists" for comparison. Rather, the list of specific telerobot primitives is used to identify task sequences where various levels of automation are appropriate and to specify the technology requirements to attain those levels. Telerobotic timelines can be constructed and cost comparisons can be made for telerobot and crew performance. Comparisons can also be made among different telerobot work systems or work system combinations (e.g., the Space Station Remote Manipulator System (SSRMS) plus Flight Telerobotic Service (FTS) versus the SSRMS plus Special Purpose Dextrous Manipulator (SPDM), etc.). Such analyses are possible using a commonly derived set of specific telerobot primitives for each task.

The syntax used in both crew-EVA and telerobot generic primitives is important because the syntax ensures that the information needed to perform analyses using specific primitives is identified. However, the syntax should also be flexible enough so that specific combinations of key words are prescribed by the situation rather than by the syntax (i.e., the syntax should

Evolution of a Task Primitive from Generic to Specific

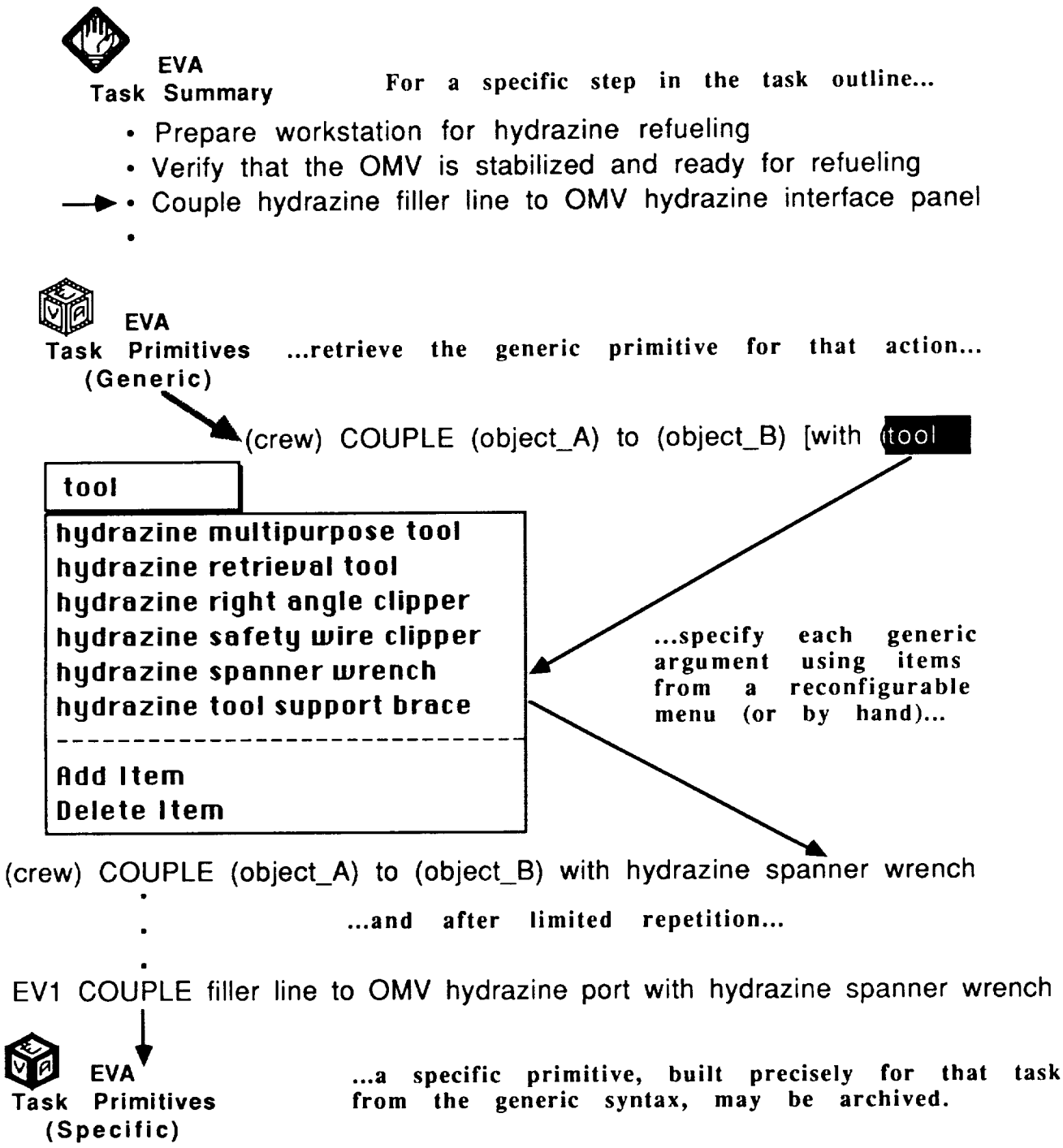
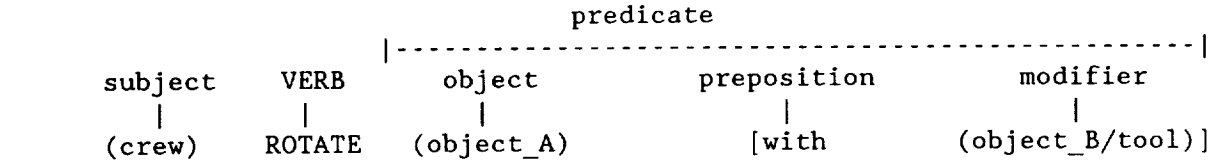


Figure 1-1. Example of Transformation of a Generic Primitive to a Specific Primitive

not confine the user). As an illustration, the following format is used for the generic crew-EVA primitive syntax:



The punctuation defines a pair of parentheses, "( )", as a generic argument (Note: all arguments are unspecified in a generic primitive). The preposition "with" is specified in this example. The square brackets "[ ]" denote an optional part of the syntax and the "/" denotes a decision point.

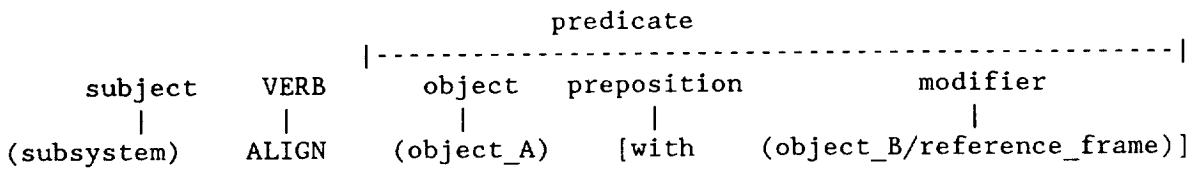
This crew-EVA primitive example illustrates the generic "subject-VERB-predicate" syntax used with all generic primitives in the crew-EVA list. The subject is always a noun and in the case of crew specified either "EV1 or EV2" from the generic "(crew)" as shown here. The predicate is formed by including a noun as the object of the verb, along with other relevant nouns catenated as modifiers with adverbs connecting them to the verb as required. The generic arguments and prepositions are similar to those in the telerobot primitives list. The software accompanying this report contains a structure for scanning or "parsing" through the primitives. The syntax parsing schemes for generic crew-EVA and telerobot primitives (Figure 1-2) highlight this similarity.

It should be noted that due to the inherent ability of humans to execute a task in more complex "chunks" than a telerobot, the number of generic arguments, prepositions, and primitives is much smaller for crew-EVA than for a telerobot (compare the parsing schemes in Figure 1-2).

Next, consider the following format for the telerobot primitive syntax:

(subsystem) ALIGN (object _A) [with (object _B/reference_frame)]

This generic telerobot primitive example illustrates the generic "subject-VERB-predicate" syntax used with all primitives in the generic telerobot primitives list. The subject is always a noun; in the case of a telerobot, either "(system)" (e.g., SSRMS, SPDM, or FTS) or "(subsystem)" as shown here. The predicate is formed by including a noun as the object of the verb, along with other relevant nouns catenated as modifiers with prepositions connecting them to the verb:



For this example the subsystem can either ALIGN an object (generically called object_A) with another object, or with a reference frame, or with something implied but not specified, in which case the optional construction "with (object_B/reference frame)" is omitted from the specific telerobot

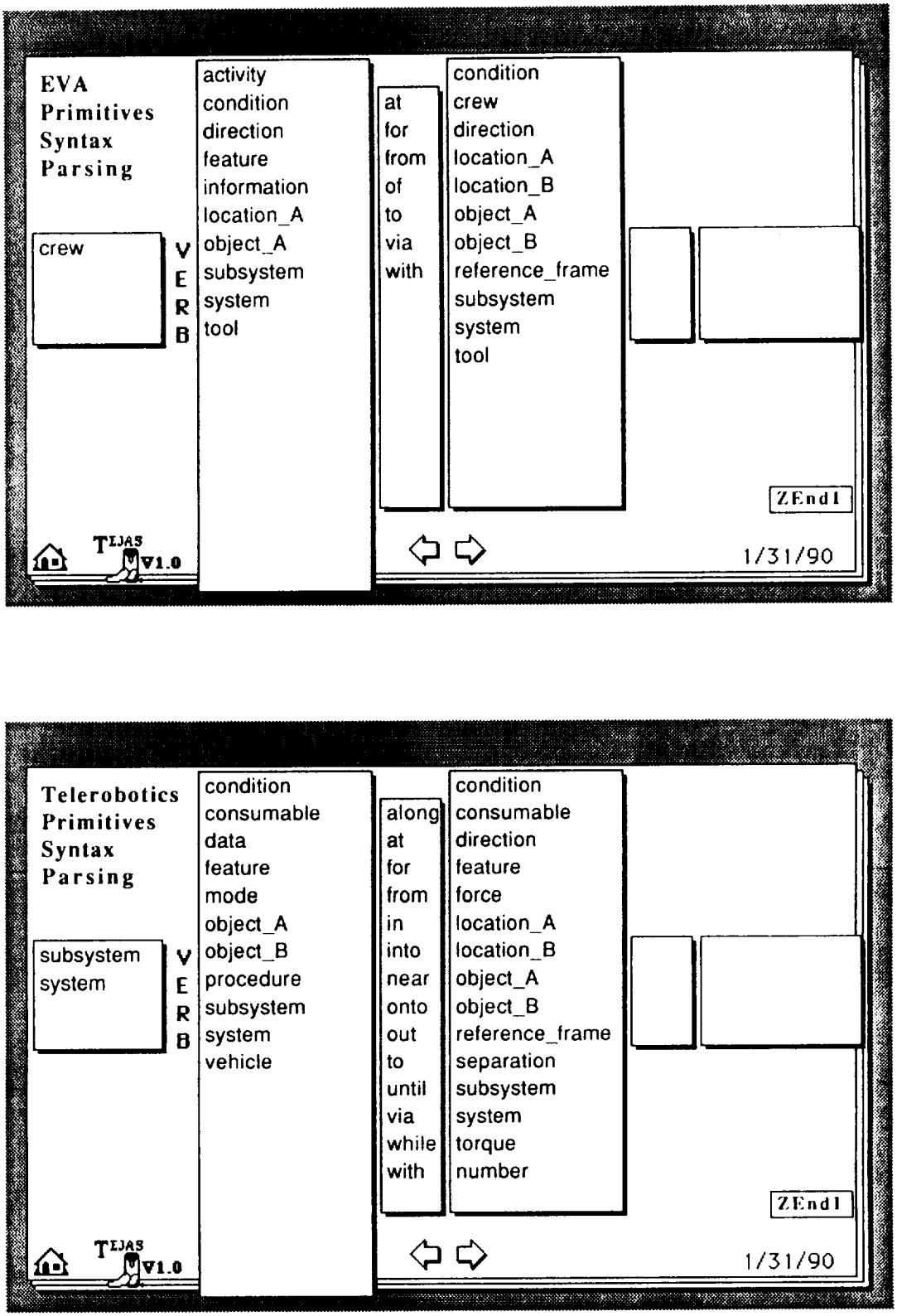


Figure 1-2. Examples of Syntax Elements

primitive. The following examples are possible specific telerobot primitives resulting from the specification of the arguments of the above generic syntax for ALIGN:

(1) motion subsystem ALIGN tool
(2) camera subsystem ALIGN camera_1 with left handle
(3) IV1 ALIGN right gripper with knob
(4) P&RS ALIGN payload with SSLVLH

Note that arguments are defined generally. IV1 refers to a crewperson at a workstation inside a pressurized environment who, working as part of the telerobot system, is teleoperating the device. Under teleoperation, the operator is the system or subsystem that performs this generic primitive (thus minimizing confusion that might result if telerobot primitives involving teleoperation were designated as IVA primitives). It is anticipated that each telerobot will have different associated acronyms for its subsystems: P&RS could be a Planning and Reasoning Subsystem. SSLVLH is the Space Station Local Vertical Local Horizontal--a reference frame centered on the SSF's point of origin.

Although the syntax has a formal structure, flexibility of definition is provided by optional fields coupled with the software capabilities. For example consider the following widely used telerobot primitive:

(system) MOVE (object_A) (condition) [direction] [to (location_A/object_A)]

The MOVE primitive illustrates the flexibility built into the syntax. The predicate consists of an object and three modifiers, two of which are optional, and one which is connected by a preposition. In this syntax structure, prepositions are not key words. They serve only to help make the final specific primitive understood (i.e., more readable). The analysis of the specific primitive resulting from specification of the arguments of the above generic primitive depends only on content, not on the order of the words, nor on any key words. This makes the analysis much easier, and much less rigid in the construction of the specific primitives. The software obviates the need for a rigid syntax structure, making commonality all the more feasible. For example, whether the specific primitive resulting from MOVE above is

(1) SSRMS MOVE satellite +X coarse rate,
or
(2) SSRMS MOVE satellite coarse rate +X 15 seconds,

both contain the condition "coarse rate," the direction +X, the object moved, and the system used. Based on the syntax shown, both are readily understood, and the user is not forced into a rigid and unfamiliar syntax. The second example has an added modifier--a duration of 15 seconds. This is acceptable and illustrates another advantage--the number of modifiers for any specific primitives is unlimited and is determined by the needs of the user.

An objective of this study is to find a common syntax that contains the required and optional elements that are needed by the task analysis community in order to construct each generic verb primitive. To the editors'

knowledge, compiling such a list has never been successfully accomplished, and the present compilation is a first proposed solution. As with all other information in these primitives lists, the syntax for each primitive (crew-EVA or telerobot) is open to evaluation. Detailed comments from the task analysis community are essential. This report and the enclosed databases are for user testing, modification, and revision. The definitions provided for each primitive are designed to guide the user's approach.

SECTION II

APPROACH

A. BACKGROUND

The development of the Space Station *Freedom* (SSF) and other space programs has led to increasing interest in the use of telerobotic systems for performing certain in-space operations. There has also been a concurrent interest in gaining a better understanding of the independent and combined roles of EVA and telerobot tasks. The need for a reliable, interactive, and easy-to-use task analysis methodology to understand and estimate the impacts of space operations on these projects has emerged. Various groups and organizations have independently developed their own task analysis methodologies for crew-EVA, for telerobotics, and for both human and telerobot performance (References 20 through 26). Many groups are pursuing similar developments on both sides of the human/machine interface boundary and expect to relate them by some synthesis process. This synthesis of human and robot performance characteristics is difficult; however, a common goal is to achieve a thorough and explicit understanding of crew-EVA and its relationship to telerobot operations.

While conducting related crew-EVA and telerobot studies (References 25, 26), it became apparent there was widespread interest in the development of a task analysis methodology and a desire to establish a consensus regarding definitions and approaches. There is also a need for better communication among study groups about shared methodological problems and for coordinating efforts in order to increase the comparability and generalizability of different studies. Specifically, there appears to be interest throughout the task analysis community to produce a standardized set of crew-EVA and telerobot task primitives, based on lists from each of the groups.

B. TASK ANALYSIS WORKSHOP

An all-day working meeting was conducted on June 7, 1989, to coincide with neutral buoyancy testing activities at McDonnell Douglas Space Systems Company (MDSSC) in Huntington Beach, California, June 6-8, 1989. MDSSC invited a cross section of the crew-EVA and telerobotics communities to view a test and demonstration of astronaut-robot cooperation under simulated microgravity conditions in its neutral buoyancy facility.

The purpose of the workshop was to bring together groups involved in the various aspects of EVA task analysis and acquaint them with the studies being done in EVA task analysis. The intent was that participants could then work on compiling a common set of terminology in order to facilitate future communications. Discussions allowed an exchange of information about approaches, assumptions, models, primitives and software tools.

The workshop was divided into three parts: (1) crew-EVA task analysis, (2) telerobot task analysis/primitives, and (3) miscellaneous. The workshop

provided an opportunity for each attending group to give a brief report on its particular interest in task analysis and to summarize its present task analysis methodology. Each group also identified problems and issues that had arisen in their work.

The morning session focused on crew-EVA task analysis. After representatives from various groups gave their presentations, the large group separated into smaller working groups to summarize the significant issues, requirements, or needs affecting the crew-EVA work presented. Each issue or requirement was associated with a statement of rationale. The results of these discussions are included in Section II-C.

The afternoon session was devoted to telerobot primitives and miscellaneous discussion items (e.g., software tools). There was an opportunity for groups to briefly present the work they were doing in this area. An attempt was made to integrate the various approaches and identify open topics and action items. Time was also devoted to resolving a number of open issues from the morning session.

The details of all the presentations are available from the individual authors (see Table i-1).

The meeting concluded with the generation of a summary set of findings, conclusions of the meeting, and assignment of action items.

C. TASK ANALYSIS WORKSHOP RESULTS

At the conclusion of the workshop, it was agreed that JPL would distribute a draft list of agreed-upon generic crew-EVA and telerobot primitives. The community would review these and return their comments to JPL for incorporation into the final lists of definitions for this report.

The results of the workshop exercise are described below.

(1) Crew-EVA Primitives

After needs and requirements were thoroughly discussed and recorded, the following points were agreed upon:

(a) The task analysis community is interested in both direct EVA planning (e.g., working directly with crew) and automation/robotics analysis (References 20 through 26). The approaches under these two headings may be different but do not appear to be incompatible.

(b) Crew-EVA primitives are defined at a higher level than telerobot primitives.

(c) There is consensus on the need for standard terminology and operational definitions for crew-EVA and telerobot primitives.

(d) There is consensus on the desirability and need for a verb-argument format for crew-EVA primitives using a standardized set of verbs.

(e) Crew-EVA primitives can be quite general until arguments such as worksite descriptions or other environmental parameters are attached to the verbs. It should be noted that the specifics of on-board spares, repair or servicing facilities, and the different logistics implications thereof were not addressed.

(2) Telerobot Primitives

(a) There is a strong correlation between the level of analysis and the definitions of primitive contents, and there remains differences in approaches among various group members that still need resolution.

(b) There is consensus on the desirability and need for a verb-argument format for the telerobot primitives using a standardized set of verbs.

(c) Arguments should be parameterized in terms of worksite attributes and assumptions about tools, equipment, and other resources, but only as placeholders for generic primitives (see definitions in Section I-G).

(d) Telerobot primitive linkages to crew-EVA primitives should be specified in terms of well-defined rules.

(3) Because of semantic difficulties, the following definitions of "primitive" were adopted at the workshop (and refined during the post-workshop analysis):

Crew-EVA Case

1. Primitive, crew-EVA (Generic): The smallest descriptive task component for a crewmember performing EVA, involving a subject (crew), an action VERB, and undefined arguments in a consistent syntax. Example Verbs: GRASP, TRANSLATE, MATE, VERIFY.

2. Primitive, crew-EVA (Specific): The smallest descriptive task component for a crewmember performing EVA, involving a subject (EV1, EV2, etc.), an action VERB, the object of that action, and external factors, all defined as specific arguments connected by prepositions, and evolving from generic primitives. Examples: EV1 GRASP wrench, EV2 TRANSLATE to MMU, EV1 ATTACH tether to slidewire, EV2 VERIFY clear of obstructions.

Telerobotics Case

1. Primitive, Telerobot (Generic): The smallest descriptive task component possible above actual coding of computer instructions (commands) to the telerobot, involving a subject, an action VERB, and undefined arguments in a consistent syntax. Example Verbs: GRASP, MOVE, STOP, ACQUIRE.

2. Primitive, Telerobot (Specific): The smallest descriptive task component possible above actual coding of computer instructions (commands) to the telerobot, involving a subject (a system or subsystem, including an operator if teleoperating), an action VERB, the object(s) of that action, and external factors, all defined as specific arguments connected by prepositions, and evolving from generic primitives. Examples: FTS GRASP ORU with gripper1; RMS MOVE PFA 0.3m +X; IV1 STOP SSRMS; vision subsystem ACQUIRE vertex A.

The comments from interested individuals were returned to JPL, where they were reviewed, analyzed, and revised as necessary to produce a new set of generic crew-EVA and telerobot primitives. Section III describes the results of the review and analysis.

D. TASK ANALYSIS WORKSHOP PARTICIPATION

Many individuals from several NASA centers and their contractors participated at various levels in the effort involved in this report. The meeting was highly interactive and each person had some part in the discussions and exchange of ideas. (For a list of participants and their contributions to the workshop, see Table i-1.)

Column 4 denoted "6/7/89 MDSSC" identifies the workshop attendees.

A number of individuals not present at the meeting but interested in the subject matter contacted JPL and requested a copy of the minutes and generic primitive lists. These individuals were also asked to return the lists with their "redlines" and comments. Other individuals obtained copies of the materials and responded with their comments. These individuals are identified in columns 4, 5, and 6.

The editors of the review comments for the primitive lists and this report are identified in last column.

A database tool was developed to manage the primitives lists. The tool contains source and history fields for each primitive to show the specific contributions of each individual. The details of these histories are presented in Appendixes B and C.

SECTION III

RESULTS

The comments and generic primitives provided by the workshop participants were reviewed and analyzed to produce a set of generic crew-EVA and telerobot primitives and a syntax for task analysis. This section summarizes the post-workshop activities and subsequent analysis. A number of observations were made as the numerous approaches, primitives, and review comments were synthesized. These observations are described below.

A. POST-WORKSHOP ANALYSIS

After reviewing the various methods of task analysis, a similar pattern of crew-EVA and telerobotics task analysis was observed. The steps of this pattern are:

(1) Name the task.

(2) Divide the task into subtasks--this can take several iterations, depending on the method employed.

(3) Develop a narrative description of the subtask, to serve as a guide.

(4) State the assumptions of the task, name the tools used, and identify the environment.

(5) State the open issues--things not decided or known (not always performed rigorously).

(6) Develop an outline of the steps in the subtask.

(7) Build the specific task from activity elements.

At step (7), the approaches appear to diverge. For example, the FTS control architecture (Reference 27) has six levels of detail (mission, service bay, task, E-move, primitive, and servo) similar to NASREM (Reference 28). This is similar to the FTS Mission Utilization Team task analysis methodology with six levels (mission, work force, tasks, E-move, primitive, servo) (Reference 21). These are similar to another approach with only three levels (main program, subroutines, primitives) (Reference 22). On closer inspection, all the approaches are attempting to perform the same function--quantify the work involved while managing the details attached to those work elements (e.g., skill level, completion time, frequency, tools needed, and cost).

The key to relating the above architectures is to use a standard source of generic task primitives and a repeatable routine for specifying their arguments in order to generate the specific primitives used on different levels of the above architectures. For example, a MOVE primitive for different architectures and levels will be traceable to the same generic primitive.

Regardless of the terminology used, generic primitives need uniform and consistent definitions in order to be useful and understandable. These definitions take the form of a well defined central verb and a syntax for its usage. The use of well-defined generic primitives enables diverse EVA and telerobotics task analysis methodologies to remain distinct, but still capable of correlation, via the common syntax used. It should be emphasized that standardization of generic primitives is a desirable result that can be extended to a variety of similar but distinct task analysis architectures. The number of levels and placement of generic primitives within the levels of these architectures is tied more closely to specific applications than to the definitions of generic primitives.

B. DEFINITIONS

One of the barriers to any form of standardization is the lack of uniform operational definitions for the terms used in the task analysis area. This is complicated by the existence of both EVA and telerobot primitives and whether they are used in a generic or specific manner. To clarify these differences, the following definitions are used:

Crew-Eva Case

1. Primitive, crew-EVA (Generic): The smallest descriptive task component for a crewmember performing EVA, involving a subject (crew), an action VERB, and undefined arguments in a consistent syntax. Example Verbs: GRASP, TRANSLATE, MATE, VERIFY.

2. Primitive, crew-EVA (Specific): The smallest descriptive task component for a crewmember performing EVA, involving a subject (EV1, EV2, etc.), an action VERB, the object of that action, and external factors, all defined as specific arguments connected by prepositions, and evolving from generic primitives. Examples: EV1 GRASP wrench, EV2 TRANSLATE to MMU, EV1 ATTACH tether to slidewire, EV2 VERIFY clear of obstructions.

Telerobotics Case

1. Primitive, Telerobot (Generic): The smallest descriptive task component possible above actual coding of computer instructions (commands) to the telerobot, involving a subject, an action VERB, and undefined arguments in a consistent syntax. Example Verbs: GRASP, MOVE, STOP, ACQUIRE.

2. Primitive, Telerobot (Specific): The smallest descriptive task component possible above actual coding of computer instructions (commands) to the telerobot, involving a subject (a system or subsystem, including an operator if teleoperating), an action VERB, the object(s) of that action, and external factors, all defined as specific arguments connected by prepositions, and evolving from generic primitives. Examples: FTS GRASP ORU with gripper1; RMS MOVE PFA 0.3m +X; IV1 STOP SSRMS; vision subsystem ACQUIRE vertex A.

C. GENERIC AND SPECIFIC PRIMITIVES

From the above definitions, note that generic primitives form the basis for specific primitives. Specific primitives directly follow from specification of the undefined arguments of a generic primitive's syntax; and although specific primitives are essential for analyzing specific tasks, generic primitives are those that are defined, standardized, and exchanged within the telerobotics and EVA task analysis communities. Generic primitives should enable description of tasks as yet unknown. They are the fundamental building blocks of sequential, timeline activity descriptions.

Each transition from a generic to specific primitive for a particular task is an individual process for a particular task. The assumptions about environment, task space, and tools must be defined for the task in order to provide a menu of specific arguments. Figure 3-1 illustrates such a menu for "tools." If there is a change in the task, the assumptions, or the open issues, the menus may change, and this may force changing the specific primitive (although the choice of its generic primitive may be unaffected). This is a natural and well-understood iterative process. An automated tool for performing this complex data management is desirable by the community. Generic crew-EVA and telerobot primitives form the primitives reference compilation for such a tool.

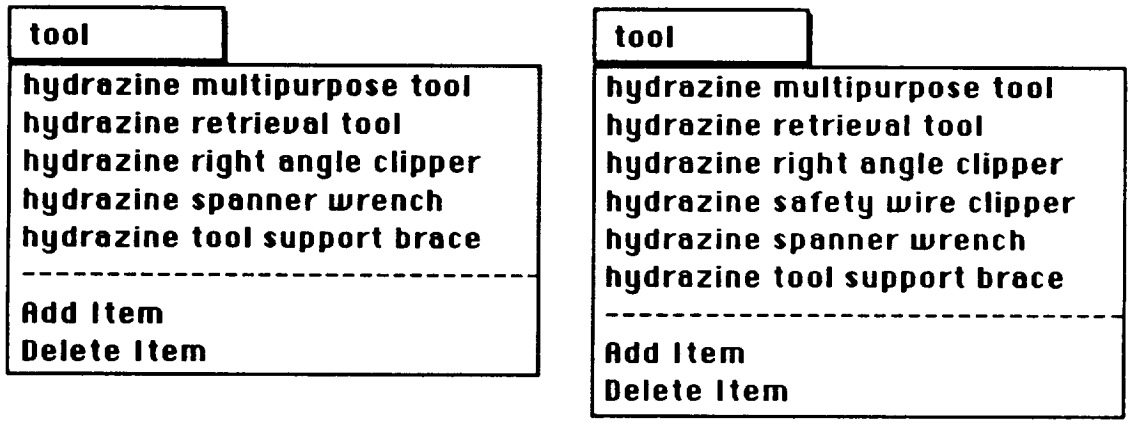


Figure 3-1. Example of Generic Syntax Argument Menu for the Generic Syntax Argument "(tool)" for EVA Primitives: (a) Before Adding Item; (b) After Adding Item.

Once a communitywide generic primitives reference compilation has been obtained, effort can shift to gathering the information needed to specify the task analysis arguments. The standardized databases that manage information on worksite attributes, the on-orbit environment, tools, equipment, and other resources are of fundamental importance. Utilization of the existing resources (e.g., The EVA Tools and Equipment Catalog, Reference 29) and creation of new ones will be essential in further development of basic tools for all methodologies. This function is normally executed by a standards committee.

Crew-EVA primitives are more complex than telerobot primitives because the human work system is more highly integrated with multiple capabilities. Thus, a smaller number of crew-EVA primitives than telerobot primitives are required to perform a given task. The majority of telerobot primitives are not compound actions because of the sequential and much less integrated nature of the telerobot work system. The degree of capability is illustrated by the crew-EVA primitive, STOW. STOW is considered an EVA primitive (for known objects with complementary interfaces) in the crew-EVA primitives list, but not a telerobot primitive.

Over time using these generic primitives will provide a checklist to prevent omission of steps from a scenario, help support a system perspective, enable trades (such as time versus design modification, cost analyses), and can thus influence hardware design by highlighting technology limitations.

Common terminology facilitates discussion and comparison of different work system groupings (e.g., two EVA crew, one EVA crew and telerobot, telerobot alone). Task primitives are the proper means of defining and communicating the correspondence between EVA and telerobotics. The linkages between work systems should be quantifiable in terms of well-defined rules. This has not yet been achieved. Early efforts (Reference 17) indicate that with universal primitives as objects, it is possible to write such rules, and if so, the links will most likely be between specific, rather than generic, primitives. This implies that the relationship between crew-EVA and telerobot primitives will be task-dependent to some extent. A desirable future capability would be to enable mixed work-system task analyses, with EVA performing tasks in conjunction with a telerobot (interactively cooperating with timelines and resource analyses performed simultaneously for each work system). The standardization of primitives is an essential stepping stone to such a capability.

SECTION IV

DISCUSSION AND CONCLUSIONS

A. DISCUSSION

The use of generic crew-EVA and telerobot primitives for planning and analysis of space operations is a new area. The lack of an accepted method for such techniques has been overtaken by a need to understand the requirements and roles of space operations. Increasing reliance on telerobot work systems as tools to reduce crew-EVA workloads focuses attention on approaches that will enable researchers to better understand how tasks are planned and implemented and how a work system is used (e.g., crew and/or telerobot).

It is anticipated that the products of this effort will prove useful to a wide variety of programs considering the use of crew-EVA and/or telerobot work systems. How the various task analyses are conducted will still vary within different applications, but the first step toward a common terminology and mechanism for communicating operations planning issues has been taken.

A major difficulty in proposing or defining standard definitions is the highly iterative revision process. The primitives described in this report will undoubtedly be reviewed and revised. It is important to note that the entire list and several additional capabilities are contained in software form for distribution (Reference 10).

B. LIMITATIONS

The first limitation is that intravehicular activity (IVA) was not examined. There may be some differences between crew-IVA and telerobot primitives performed by an IVA telerobot, although it is more likely such differences would be manifested in the form of time duration differences rather than definitions.

A second limitation is that although many individuals and organizations participated in the first workshop, the announcement of the workshop was limited. Therefore, review and further analysis are recommended. Such a prospect was suggested at the first workshop but held in abeyance pending release of the present report.

C. FUTURE TOPICS

In future study the first area of concern will be an examination of the IVA primitives issue to determine whether these elements are significantly different and additional development is needed.

The second area will include compiling a definition of requirements for a software tool to enable rapid development of crew-EVA and telerobot timelines.

A third area of future study is the application of these primitives to the complete analysis of a planned system. An application will serve to raise issues important to future utilization of the primitives for task analysis.

Finally, the question of an additional workshop should be considered with the objective of formalizing the generic primitives as a standard.

D. CONCLUSIONS

A number of products and conclusions were drawn from the workshop and follow-on activities:

(1) The documentation of a version 1.0 reference compilation of crew-EVA generic task analysis primitives is intended for use in crew-EVA task planning and analysis. The list of generic primitives, sorted by action verbs, is contained in Section V-A. The verbs are listed in alphabetical order followed by the definition, syntax, like verbs, and antonym. The historical evolution of the list and syntax is presented in Appendix B for traceability purposes.

(2) The documentation of a version 1.0 reference compilation of telerobot generic task analysis primitives is intended for use in telerobot operations planning and analysis. The list of generic primitives, sorted by action verbs, is contained in Section V-B. The verbs are in alphabetical order followed by the definition, syntax, like verbs, and antonym. The historical evolution of the list and syntax is presented in Appendix C for traceability purposes.

(3) The version 1.0 software database containing the lists of generic primitives is included with this report for use, modification, or review by any interested party. Section VI describes this tool and its usage. A software tool for the purposes of managing the primitives lists and creating crew-EVA and telerobot timelines is included with this report. User feedback is requested in order to evolve a standardized reference and revision procedures that have been built in to manage changes.

(4) The generic crew-EVA and telerobot primitives lists provide a language for communicating and analyzing in-space tasks for the purposes of better understanding effective and efficient roles for both crew and telerobots (Section IV).

(5) A task-specific primitive results from specification of the generic arguments of a generic primitive. Once specified, a set of task-specific primitives becomes a "script" for operation of the work system. While it is not possible to standardize task-specific primitives, it is feasible to standardize generic primitives and a syntax. This report documents a standard proposed by members of the task analysis community.

(6) Insights were obtained on how task analyses are currently being performed by a variety of organizations. Although the basic methods are similar, a key problem area is the lack of definitions and standardization. The confusion in terminology stems from a need for operational definitions. A description of the basic task analysis approach and suggested definitions is presented in Section III-A.

(7) The next step in the development of a tool for generating task-specific "scripts" from a set of generic task analysis primitives requires that existing databases of the support infrastructure be imported into the task analysis process (e.g., the "EVA Tools and Equipment Catalog"). Such databases contain the arguments for generic primitives that facilitate conversion of generic primitives to specific primitives for a specific task. It is recommended that the task analysis community, in conjunction with the appropriate standards committees, conduct such activities to translate these hard copy desk references to electronic media. It is also recommended that a second workshop be held to refine the existing standard and remaining requirements.

The intent of this activity is to bring members of the task analysis community closer together via an improved language for communicating concepts. The purpose of this common langugage is to provide a means for describing space operations in a well-defined manner to better understand the technical and economic feasibility of such operations in the future.

SECTION V

GENERIC CREW-EVA AND TELEROBOT TASK PRIMITIVES REFERENCE COMPILATION

A. GENERIC CREW-EVA PRIMITIVES REFERENCE COMPILATION

The generic crew-EVA primitives provide a means for planning crew-EVA excursions and estimating time requirements. For any given task (e.g., ORU change-out), the generic crew-EVA primitives are used in a step-by-step manner to construct crew-EVA timelines. The specific times for the specific primitives derived from these generic primitives can be taken from estimates made under neutral buoyancy conditions, time model estimates from on-orbit experience, or laboratory measurements.

Each generic crew-EVA primitive verb is listed in alphabetical order followed by its definition, syntax, like verbs, and antonym. The syntax and format of the generic crew-EVA primitives are described in Section I-G. The historical derivation of these primitives is contained in Appendix B including the comments received, the resolution of those comments, and if applicable, the reasons for deletion of the verb. This is a part of the "total traceability" for this reference compilation.

Verb:	ACTIVATE
Syntax:	(crew) ACTIVATE (system)
Like Verbs:	RESUME
Antonym:	SHUTDOWN
Definition:	To change the system state from inoperative or standby to operative. This includes power up and initialization.

Verb:	ADJUST
Syntax:	
Like Verbs:	
Antonym:	
Definition:	DELETED

Verb:	ADJUST
Syntax:	(crew) ADJUST (condition) of (object_A)
Like Verbs:	
Antonym:	
Definition:	To change the orientation or setting of an object.

Verb:	ALIGN
Syntax:	(crew) ALIGN (object_A) with (object_B/reference_frame)
Like Verbs:	
Antonym:	
Definition:	To position an object with respect to specified feature(s) (e.g., edge) of another object or reference frame.

Verb:	ASSEMBLE
Syntax:	(crew) ASSEMBLE (tool)
Like Verbs:	
Antonym:	DISASSEMBLE
Definition:	To fit or put together parts of a tool or instrument for use as a constructed whole.

Verb: ATTACH
Syntax:
Like Verbs:
Antonym:
Definition: DELETED

Verb: BERTH
Syntax:
Like Verbs:
Antonym: UNBERTH
Definition: DELETED

Verb: BOLT
Syntax:
Like Verbs: INSTALL
Antonym: UNBOLT
Definition: DELETED

Verb: CHECKOUT
Syntax:
Like Verbs:
Antonym:
Definition: DELETED

Verb: CLEAN
Syntax: (crew) CLEAN (object_A) [at (location_A/feature)]
Like Verbs:
Antonym: none
Definition: To remove unwanted contaminants, impurities, or objects from a surface, using an active agent (e.g a fluid, brush, etc.).

Verb:	CLOSE
Syntax:	(crew) CLOSE (object_A)
Like Verbs:	
Antonym:	OPEN
Definition:	To make an enclosure inaccessible from without, or block throughput in a channel, conduit or pipeline, by placing an object (i.e., a door, hatch or valve) to obstruct the path of access for objects or materials through the opening into the enclosure or channel.

Verb:	CLOSEOUT
Syntax:	
Like Verbs:	
Antonym:	
Definition:	DELETED

Verb:	COLLECT
Syntax:	
Like Verbs:	
Antonym:	
Definition:	DELETED

Verb:	COMMUNICATE
Syntax:	(crew) COMMUNICATE (information) with (crew/subsystem)
Like Verbs:	
Antonym:	
Definition:	To exchange information with another person or (sub)system, usually (but not necessarily) through speech.

Verb:	CONFIGURE
Syntax:	(crew) CONFIGURE (object_A) [(object_B)]
Like Verbs:	
Antonym:	
Definition:	To arrange an object(s) in a specific manner (e.g., to arrange tools on a toolboard).

Verb: CONNECT
Syntax:
Like Verbs:
Antonym:
Definition: DELETED

Verb: CONSTRUCT
Syntax:
Like Verbs:
Antonym:
Definition: DELETED

Verb: COORDINATE
Syntax:
Like Verbs:
Antonym:
Definition: DELETED

Verb: COVER
Syntax:
Like Verbs:
Antonym: UNCOVER
Definition: DELETED

Verb: DEACTIVATE
Syntax:
Like Verbs:
Antonym:
Definition: DELETED

Verb:	DECONTAMINATE
Syntax:	
Like Verbs:	
Antonym:	
Definition:	DELETED

Verb:	DEMATE
Syntax:	(crew) DEMATE (object_A) [from (object_B)] [(condition)]
Like Verbs:	RELEASE
Antonym:	MATE
Definition:	To take apart or separate joined parts (object A from object B), e.g., detach Velcro interface, unplug power umbilical; condition: type of connection or mating (e.g., quick connect, captive pin, threaded interface, etc.).

Verb:	DEPLOY
Syntax:	(crew) DEPLOY (system) with (subsystem)
Like Verbs:	UNSTOW
Antonym:	STOW
Definition:	To move, unfold, or drive a mechanical appendage (e.g., a manipulator, an antenna boom, etc.) into its operational configuration. Like UNSTOW, this connotes a simple, rehearsed operation that need not be broken down into a sequence of simpler primitives.

Verb:	DETACH
Syntax:	
Like Verbs:	
Antonym:	ATTACH
Definition:	DELETED

Verb:	DISCONNECT
Syntax:	
Like Verbs:	DEMATE
Antonym:	CONNECT
Definition:	DELETED

Verb:	EGRESS
Syntax:	(crew) EGRESS (object_A)
Like Verbs:	
Antonym:	INGRESS
Definition:	To go out of or exit an enclosure for all or part of the body, e.g., a foot restraint or airlock.

Verb:	ERECT
Syntax:	
Like Verbs:	ASSEMBLE
Antonym:	
Definition:	DELETED

Verb:	GRAPPLE
Syntax:	
Like Verbs:	
Antonym:	
Definition:	DELETED

Verb:	GRASP
Syntax:	(crew) GRASP (object_A) [with (tool)]
Like Verbs:	HOLD
Antonym:	RELEASE
Definition:	To grip an object manually or by mechanical means through some hand-held tool or instrument (intended to extend the crewperson's reach); to secure a hold upon an object.

Verb:	GUIDE
Syntax:	
Like Verbs:	
Antonym:	
Definition:	DELETED

Verb:	HANDLE
Syntax:	
Like Verbs:	
Antonym:	
Definition:	DELETED

Verb:	HANDOFF
Syntax:	(crew) HANDOFF (object_A) to (crew/system)
Like Verbs:	
Antonym:	none
Definition:	To give an object to another EVA crewperson or telerobotics work system, relinquishing control of and responsibility for that object to the other crewperson or system.

Verb:	HOLD
Syntax:	(crew) HOLD (object_A)
Like Verbs:	GRASP
Antonym:	RELEASE
Definition:	To manually retain a grasp on an object during the performance of a task in order to restrain or control the position of the object without a mechanical attachment.

Verb:	IMPLEMENT
Syntax:	
Like Verbs:	
Antonym:	
Definition:	DELETED

Verb:	INGRESS
Syntax:	(crew) INGRESS (object_A)
Like Verbs:	
Antonym:	EGRESS
Definition:	To insert all or part of the body into an enclosure or holding device, e.g., a foot restraint or airlock.

Verb:	INPUT
Syntax:	
Like Verbs:	
Antonym:	
Definition:	DELETED

Verb:	INSPECT
Syntax:	(crew) INSPECT (object_A)
Like Verbs:	MONITOR
Antonym:	none
Definition:	To examine an object carefully noting status or condition in relation to a list/set of nominal characteristics.

Verb:	INSTALL
Syntax:	(crew) INSTALL (object_A) in/on (object_B)
Like Verbs:	MATE
Antonym:	REMOVE
Definition:	To attach one object in or on another (i.e., a cover, a protective envelope such as a micrometeor shield or MLI, fasteners, etc.), either by hands-on or with the use of a manual or powered tool. This definition is to cover other attachment activities that would otherwise require a large number of other primitives for latching, bolting, pinning, tying, or whatever.

Verb:	LATCH
Syntax:	
Like Verbs:	SECURE
Antonym:	UNLATCH
Definition:	DELETED

Verb:	LOAD
Syntax:	
Like Verbs:	
Antonym:	
Definition:	DELETED

Verb:	LOOSEN
Syntax:	
Like Verbs:	
Antonym:	
Definition:	DELETED

Verb:	LUBRICATE
Syntax:	(crew) LUBRICATE (object_A) with (tool)
Like Verbs:	
Antonym:	
Definition:	To apply a substance to the surface(s) of an object in order to reduce its coefficient of static and dynamic friction against another object.

Verb:	MANEUVER
Syntax:	(crew) MANEUVER [(condition)] (object_A)
Like Verbs:	ROTATE
Antonym:	none
Definition:	To manually move an object from one location to another by making a series of changes in direction or position; condition: small (obj < 1 cu.ft.), medium (obj < 1650 lbs), large (obj > 1650 lbs), or flexible (e.g., hose, cable, multi-layered insulation (MLI)).

Verb:	MATE
Syntax:	(crew) MATE (condition) (object_A) to (object_B)
Like Verbs:	INSTALL
Antonym:	DEMATE
Definition:	To join or fit complementary parts (object A to object B); e.g., 'MATE power umbilical'. Condition: type of connection or mating (e.g., quick connect, captive pin, threaded interface, etc.).

Verb:	MEASURE
Syntax:	(crew) MEASURE [(feature) of] (object_A)
Like Verbs:	
Antonym:	none
Definition:	To determine the physical dimension(s) of an object (or a particular feature of an object) against a standard.

Verb:	MONITOR
Syntax:	(crew) MONITOR (object_A/activity)
Like Verbs:	INSPECT
Antonym:	none
Definition:	To attentatively watch a dynamic system or process in order to detect a change in state or condition, either appropriate or unexpected.

Verb:	OBSERVE
Syntax:	
Like Verbs:	MONITOR
Antonym:	
Definition:	DELETED

Verb:	OBTAIN
Syntax:	
Like Verbs:	
Antonym:	
Definition:	DELETED

Verb:	OPEN
Syntax:	(crew) OPEN (object_A)
Like Verbs:	
Antonym:	CLOSE
Definition:	To make an enclosure or conduit accessible from without, or to free throughput in a channel, by removing obstruction(s) to the path of access for objects or materials (i.e., applies to doors and valves).

Verb:	PHOTOGRAPH
Syntax:	
Like Verbs:	
Antonym:	
Definition:	DELETED

Verb:	POINT
Syntax:	
Like Verbs:	
Antonym:	
Definition:	DELETED

Verb:	POSITION
Syntax:	
Like Verbs:	
Antonym:	
Definition:	DELETED

Verb:	PROCESS
Syntax:	
Like Verbs:	
Antonym:	
Definition:	DELETED

Verb:	PULL
Syntax:	(crew) PULL (object_A) [(direction)] [to (location_A)]
Like Verbs:	MANEUVER
Antonym:	PUSH
Definition:	To exert force on an object toward the center of the body by use of the arm(s) and hand(s) gripping the object; implies that the astronaut is secured by a handhold and/or foothold (single foot in foot restraint).

Verb:	PUSH
Syntax:	(crew) PUSH (object_A) [(direction)] [to (location_A)]
Like Verbs:	MANEUVER
Antonym:	PULL
Definition:	To exert force against an object away from the center of the body, usually (although not always) with the arms, but also [optionally] with another held object, or even the feet; implies that the astronaut is secured by a handhold and/or foothold (single foot in foot restraint).

Verb:	QUERY
Syntax:	
Like Verbs:	
Antonym:	
Definition:	DELETED

Verb:	RECHARGE
Syntax:	
Like Verbs:	
Antonym:	
Definition:	DELETED

Verb:	RECORD
Syntax:	(crew) RECORD (information) with (tool)
Like Verbs:	MONITOR
Antonym:	none
Definition:	To capture and store information for later recall through the application of a hand-held instrument (e.g., SLR camera for photos, video camera for video, etc.).

Verb:	RELEASE
Syntax:	(crew) RELEASE (object_A) [with (object_B/system)]
Like Verbs:	DEMATE
Antonym:	SECURE
Definition:	To free from restraint of a crewmember or a mechanical device; to open the retaining components on an enveloping end effector (such as the RMS – a system) or a dedicated mechanism (such as a latch or tether – object_B).

Verb:	REMOVE
Syntax:	(crew) REMOVE (object_A) [from (object_B)] [with (tool)]
Like Verbs:	DEMATE
Antonym:	INSTALL
Definition:	To detach one object from another (i.e. a cover, a protective envelope such as a micrometeor shield or MLI, fasteners, etc.), either by hands-on or with the use of a manual or powered tool. This definition is to cover other detachment activities that would otherwise require a large number of other primitives for latching, bolting, pinning, tying or whatever.

Verb: REPORT
Syntax:
Like Verbs:
Antonym:
Definition: DELETED

Verb: RESTRAIN
Syntax:
Like Verbs:
Antonym:
Definition: DELETED

Verb: RESUME
Syntax: (crew) RESUME (activity)
Like Verbs: ACTIVATE
Antonym: STOP
Definition: To continue an operation previously halted, without having to reinitialize or restart from the beginning.

Verb: RESUPPLY
Syntax:
Like Verbs:
Antonym:
Definition: DELETED

Verb: RETRACT
Syntax:
Like Verbs:
Antonym:
Definition: DELETED

Verb:	ROTATE
Syntax:	(crew) ROTATE (object_A) [with (object_B/tool)]
Like Verbs:	MANEUVER
Antonym:	none
Definition:	To turn an object repetitively, either manually (through an EMU glove) or with a tool (e.g., in order to loosen or tighten an interface).

Verb:	ROUTE
Syntax:	
Like Verbs:	
Antonym:	
Definition:	DELETED

Verb:	SECURE
Syntax:	(crew) SECURE (object_A) [with (object_B)]
Like Verbs:	HOLD
Antonym:	RELEASE
Definition:	To fasten an object(s) for restraint (e.g., by means of a tether or latch – object_B).

Verb:	SELECT
Syntax:	(crew) SELECT (object_A)
Like Verbs:	
Antonym:	
Definition:	To choose a preferred object from a number of alternatives (e.g., choosing a tool from a tool locker).

Verb:	SHUTDOWN
Syntax:	(crew) SHUTDOWN (system/subsystem)
Like Verbs:	STOP
Antonym:	ACTIVATE
Definition:	To change the (sub)system state from operative to standby or inoperative. This includes system power down sequence.

Verb:	SOLVE
Syntax:	
Like Verbs:	
Antonym:	
Definition:	DELETED

Verb:	STABILIZE
Syntax:	(crew) STABILIZE (object_A)
Like Verbs:	ALIGN
Antonym:	none
Definition:	To dampen or eliminate motion of an object about one or more of its axes.

Verb:	STANDBY
Syntax:	(crew) STANDBY
Like Verbs:	SHUTDOWN
Antonym:	
Definition:	To wait, without activity, ready to resume operations on notification from ground control, another EVA crewperson, or onboard (IVA) control.

Verb:	STOP
Syntax:	(crew) STOP (activity)
Like Verbs:	SHUTDOWN
Antonym:	RESUME
Definition:	To immediately halt the current activity. Usually followed by a new instruction, question, or STANDBY call.

Verb:	STORE
Syntax:	
Like Verbs:	
Antonym:	
Definition:	DELETED

Verb:	STOW
Syntax:	(crew) STOW (object_A) [at (location_A)] [in/on (object_B)]
Like Verbs:	CLOSEOUT
Antonym:	UNSTOW
Definition:	To place and secure objects in a temporary or permanent storage location in a simple, rehearsed manual activity. This is existing, useful terminology. It connotes simple ("routine") stowing procedures; these are so learned, so practiced, that the crew knows how to do them by simply saying "stow" or "unstow" (the wrench, the PFR, etc.). With more complicated equipment such as the MMU, or unique devices with which they may not be as familiar, a step-by-step primitive callout might be necessary...but not always.

Verb:	TERMINATE
Syntax:	
Like Verbs:	
Antonym:	
Definition:	DELETED

Verb:	TEST
Syntax:	(crew) TEST (object/system/subsystem) [for (condition)]
Like Verbs:	INSPECT
Antonym:	
Definition:	To evaluate the physical and functional qualities of an object, subsystem or system via execution of a preprogrammed sequence (frequently, instructions from a microprocessor).

Verb:	TIGHTEN
Syntax:	
Like Verbs:	
Antonym:	
Definition:	DELETED

Verb:	TRANSFER
Syntax:	
Like Verbs:	
Antonym:	
Definition:	DELETED

Verb:	TRANSLATE
Syntax:	(crew) TRANSLATE to (location_A) [via (object_A/system/subsystem)]
Like Verbs:	TRANSPORT
Antonym:	none
Definition:	To move crew to a location by means of an object (e.g., foot and/or hand hold, slidewire), with kinetic energy supplied by their own muscle actions.

Verb:	TRANSPORT
Syntax:	(crew) TRANSPORT (object_A) [from (location_A)] to (location_B) [via
Like Verbs:	POSITION
Antonym:	none
Definition:	To move an object from one location to another by means of crewmember translation with the object attached somehow to their person.

Verb:	UNBERTH
Syntax:	
Like Verbs:	
Antonym:	BERTH
Definition:	DELETED

Verb:	UNBOLT
Syntax:	
Like Verbs:	REMOVE
Antonym:	BOLT
Definition:	DELETED

Verb:	UNCOVER
Syntax:	
Like Verbs:	REMOVE
Antonym:	COVER
Definition:	DELETED

Verb:	UNLATCH
Syntax:	
Like Verbs:	RELEASE
Antonym:	LATCH
Definition:	DELETED

Verb:	UNSTOW
Syntax:	(crew) UNSTOW (object_A/tool) [from (location_A)]
Like Verbs:	DEPLOY
Antonym:	STOW
Definition:	To take objects from storage location in a rehearsed set of simple manual activities. This is for simple ("routine") unstowing procedures; these are so learned, so practiced, that the crew knows how to do them by simply saying "stow" or "unstow" (the wrench, the PFR, etc.). With more complicated equipment such as the MMU, or unique devices with which they may not be as familiar, a step-by-step primitive callout might be necessary – but not always.

Verb:	VERIFY
Syntax:	(crew) VERIFY (condition)
Like Verbs:	
Antonym:	
Definition:	To confirm that a system, subsystem, or process is in an expected state or condition, through visual or other means; to confirm the accuracy or correctness of a condition.

Verb:	VIDEOTAPE
Syntax:	
Like Verbs:	
Antonym:	
Definition:	DELETED

B. GENERIC TELEROBOT PRIMITIVES REFERENCE COMPILATION

The generic telerobot primitives provide a means for planning telerobot tasks and estimating potential crew-EVA time savings. The generic telerobot primitives are used to construct procedures for the telerobot to execute the required operations. Although a real-time action invoked by pushing a hand controller would result in a sequence of MOVE primitives, the concept of generic telerobot primitives allows developers to create autonomous command sequences via procedures that enable subsets of task actions to be performed automatically.

Unlike generic crew-EVA primitives, the generic telerobot primitives must be linked or mapped to an assumed technology configuration in order to establish whether the procedure is capable of executing the required actions. Thus, as different technologies mature, procedures and telerobot primitives will begin to aggregate and absorb extraneous functions. For example, to grasp an object in an early configuration might involve numerous MOVE, LOCATE, INSPECT, IDENTIFY, MOVE, LOCATE, INSPECT, IDENTIFY,... etc. However, an advanced system might combine these functions with advanced capabilities into "GET (X)." The capabilities of the telerobot work system are technology-related and the telerobot primitives that will perform these functions must be linked to those technologies when used for specific task analyses.

Each telerobot primitive verb is listed in alphabetical order followed by its definition, syntax, like verbs, and antonym. The format of the generic telerobot primitives is described in Section I-G. The historical derivation of these primitives is contained in Appendix C, including the comments received, the resolution of those comments, and if applicable, the reasons for deletion of the verb. This is part of the "total traceability" for this reference compilation.

Verb:	ACQUIRE
Syntax:	(subsystem) ACQUIRE (object_A) [near (location_A)] with (subsystem)
Like Verbs:	EXTRACT feature
Antonym:	none
Definition:	To search and encounter an object (target) with a non-contact sensory system; may involve annunciation (to an operator or a planning and reasoning subsystem) when sensed. Requires matching of a previously known object to a model, and fails if the model is incorrect. Does not specify method of sensing, matching or annunciation.

Verb:	ACTIVATE
Syntax:	(system) ACTIVATE (subsystem)
Like Verbs:	INITIALIZE
Antonym:	DEACTIVATE
Definition:	To turn power on to a subsystem (e.g., a sensor, hand controller, etc.) or peripheral device (e.g., an end effector, power tool, etc.).

Verb:	ACTUATE
Syntax:	
Like Verbs:	
Antonym:	
Definition:	DELETED FROM V1.0

Verb:	ADJUST
Syntax:	(system) ADJUST (object_A) to (condition)
Like Verbs:	ALIGN
Antonym:	none
Definition:	To place or return out-of-tolerance objects to correct position or condition. Can be done throughout a task and can be a constant process, whereas CALIBRATE is done one time, before a task is even started, and deals with subsystems instead of objects.

Verb:	ALIGN
Syntax:	(subsystem) ALIGN (object_A) [with (object_B/reference_frame)]
Like Verbs:	ADJUST
Antonym:	none
Definition:	To position an object into correspondence with a reference frame centered on a feature of another object, or to another specified reference frame, without

moving the object from its current location (i.e., through a combination of rotations of the object).

Verb:	ANALYZE
Syntax:	(subsystem) ANALYZE (data) [for (condition)]
Like Verbs:	COMPARE
Antonym:	none
Definition:	To process data (esp. from sensors) for information, by applying computational, logical, relational, or other rules and algorithms.

Verb:	APPROACH
Syntax:	
Like Verbs:	
Antonym:	
Definition:	DELETED FROM V1.0

Verb:	ASSEMBLE
Syntax:	
Like Verbs:	
Antonym:	DISASSEMBLE
Definition:	DELETED FROM V1.0

Verb:	ATTACH
Syntax:	(system) ATTACH (object_A) to (object_B/feature)
Like Verbs:	COUPLE
Antonym:	DETACH
Definition:	To join one complementary object to another object (or feature), to make a physical connection (e.g., seating a tool on a fastener, or a fastener in a complementary opening); implies the presence of complementary shapes at the interface.

Verb:	BERTH
Syntax:	(system) BERTH (vehicle) to (object_B)
Like Verbs:	ATTACH
Antonym:	UNBERTH
Definition:	To place, using a manipulator arm, a vehicle (spacecraft) on a positioning and/or retention system equipped with a fixture specifically for that purpose.

Verb:	CALIBRATE
Syntax:	(system) CALIBRATE (system/subsystem) [to (condition)]
Like Verbs:	ADJUST
Antonym:	none
Definition:	To adjust a telerobot system or subsystem to a performance standard; implies work is halted while this takes place, and the subsystem performs this primitive to the exclusion of all others. There are many kinds of calibration activities: to identify arm parameters; to send servoed arms/grippers to precise locations; to do database calibration, using an arm as a measuring device by resolving the arm joint configuration to the arm's base against another reference frame; to do camera calibration by taking measurements of the field of view containing a known object, and resolving the camera parameters by counting or locating pixels.

Verb:	CAPTURE
Syntax:	(subsystem) CAPTURE (object_A)
Like Verbs:	GRAPPLE
Antonym:	RELEASE
Definition:	To restrict or confine motion (degrees of freedom) between object and subsystem; also, to close the snares on a cable-tension end effector, such as the Orbiter RMS, or a dedicated mechanism (such as a latch).

Verb:	CHANGE-OUT
Syntax:	
Like Verbs:	
Antonym:	
Definition:	DELETED FROM V1.0

Verb:	CHECKOUT
Syntax:	(system) CHECKOUT (system/subsystem/object_A)
Like Verbs:	CALIBRATE
Antonym:	none
Definition:	To perform a proceduralized test of a system, subsystem, or object, of either the telerobot itself or a spacecraft on which it is working, in order to demonstrate operational readiness.

Verb:	CLEAN
Syntax:	
Like Verbs:	
Antonym:	none
Definition:	DELETED FROM V1.0

Verb:	CLOSE
Syntax:	(system) CLOSE (object_A)
Like Verbs:	
Antonym:	OPEN
Definition:	To make an enclosure inaccessible from without, or block throughput in a channel, by obstructing the path of access for objects or material (i.e., applies to doors and valves).

Verb:	CLOSE gripper
Syntax:	(system) CLOSE gripper (subsystem) [to (force)] [to (separation)]
Like Verbs:	GRASP
Antonym:	OPEN gripper
Definition:	To move the touch pads on fingers of a multi-fingered end effector closer together to a specified separation or feedback force; does not imply that the gripper is or is not grasping an object.

Verb:	COMPARE
Syntax:	(subsystem) COMPARE (data) to (data)
Like Verbs:	ANALYZE
Antonym:	none
Definition:	To examine two or more data to discover similarities or differences to an existing value or model.

Verb:	COMPLY
Syntax:	(system) COMPLY with (subsystem/system)
Like Verbs:	
Antonym:	none
Definition:	To allow a manipulator arm to relax and react 'naturally' (kinematically as dictated by undriven joint and link properties) to forces exerted on it by another subsystem (e.g., its own end effector executing a GRASP primitive, or another manipulator moving an object to which both are grasped or grappled in unequal dual-arm operations).

Verb:	COMPUTE
Syntax:	
Like Verbs:	ANALYZE
Antonym:	none
Definition:	DELETED FROM V1.0

Verb:	CONFIGURE
Syntax:	(system) CONFIGURE (subsystem) with (condition)
Like Verbs:	CALIBRATE
Antonym:	none
Definition:	To set up a telerobot's control system for operation, esp. in a particular way, with conditions that may include gain levels, damping ratios, a particular reference frame (e.g., robot-centered, tool-centered, SSLVLH or object-centered), or trajectory mode (ballistic, which implies a constant force vector, or straight newtonian) against which the control system resolves motion, etc.

Verb:	COUPLE
Syntax:	(system) COUPLE (object_A) to (object_B)
Like Verbs:	ATTACH
Antonym:	DECOUPLE
Definition:	To bring securely together two complementary connectors of an automated power/data/fluid interface, not acting as the ends of umbilicals.

Verb:	CUT
Syntax:	(subsystem) CUT (object_A) at (location_A) [with (object_B)]
Like Verbs:	
Antonym:	none
Definition:	To physical rend apart, divide or sever, with a sharp instrument, an object or material (e.g., insulation) that is not an assembly; usually a tool (object B here) would be specified for the job, invoking a method.

Verb:	DEACTIVATE
Syntax:	(subsystem) DEACTIVATE (subsystem)
Like Verbs:	POWER
Antonym:	ACTIVATE
Definition:	To turn off power to a subsystem (e.g., a sensor, hand controller, etc.) or peripheral device (e.g., an end effector, power tool, etc.).

Verb:	DECONTAMINATE
Syntax:	
Like Verbs:	
Antonym:	
Definition:	DELETED FROM V1.0

Verb:	DECOUPLE
Syntax:	(system) DECOUPLE (object_A) from (object_B)
Like Verbs:	DEMATE
Antonym:	COUPLE
Definition:	To separate two complementary connectors of an automated power/data/fluid interface, not acting as the ends of umbilicals.

Verb:	DEMATE
Syntax:	(system) DEMATE (object_A) from (object_B)
Like Verbs:	DECOUPLE
Antonym:	MATE
Definition:	To disconnect an umbilical (only) with its interface through complementary connectors.

Verb:	DEPLOY
Syntax:	(system) DEPLOY (system/subsystem)
Like Verbs:	UNSTOW
Antonym:	RETRACT
Definition:	To move a mechanical appendage (e.g., a manipulator, an antenna boom, etc.) into its operational configuration.

Verb:	DEPRESSURIZE
Syntax:	
Like Verbs:	
Antonym:	PRESSURIZE
Definition:	DELETED FROM V1.0

Verb:	DERIGIDIZE
Syntax:	(system) DERIGIDIZE (subsystem)
Like Verbs:	OPEN gripper
Antonym:	RIGIDIZE
Definition:	To loosen the snares of a cable-tension end effector, such as the Orbiter RMS's, usually as part of releasing a compatible grapple fixture or object that had been snugged to that end effector.

Verb:	DESIGNATE
Syntax:	(system) DESIGNATE (object_A)
Like Verbs:	IDENTIFY
Antonym:	none
Definition:	To indicate a feature or object on a returned video scene, register (locate) it through the use of camera models, and assign a semantic label for future reference; may be effected by an operator ('operator designate') or an automated system.

Verb:	DETACH
Syntax:	(system) DETACH (object_A) from (object_B)
Like Verbs:	UNBOLT
Antonym:	ATTACH
Definition:	To take apart, to unfasten, to separate one object from another, to break a physical connection; implies that the objects are in physical contact with each other, but does not specify by what method this contact was effected or maintained.

Verb:	DIAGNOSE
Syntax:	(system) DIAGNOSE (condition)
Like Verbs:	ANALYZE
Antonym:	none
Definition:	To determine by examination and analysis of available data the nature and circumstances of an anomalous condition.

Verb:	DISASSEMBLE
Syntax:	
Like Verbs:	
Antonym:	ASSEMBLE
Definition:	DELETED FROM V1.0

Verb:	DOCK
Syntax:	
Like Verbs:	
Antonym:	UNDOCK
Definition:	DELETED FROM V1.0

Verb:	DOWNLOAD
Syntax:	(system) DOWNLOAD (data) to (subsystem)
Like Verbs:	DUMP
Antonym:	UPLOAD
Definition:	To transfer software or data from an actuating computer system to a receiving computer system, e.g., from an on-orbit telerobot system computer to a ground system, or to another on-orbit spacecraft or system.

Verb:	DRAIN
Syntax:	(subsystem) DRAIN [(consumable) from] (subsystem) [until (condition)]
Like Verbs:	PURGE
Antonym:	FILL
Definition:	To remove consumable (fluid, gas, cryogen) from a reservoir, esp. fuel and coolant for spacecraft. Involves determining relative conditions between 'empty' and 'full', usually by means of in-place instrumentation.

Verb:	DUMP
Syntax:	(system) DUMP (subsystem) to (subsystem)
Like Verbs:	DOWNLOAD
Antonym:	none
Definition:	To transfer all data and software in a telerobot's computing subsystem to storage, usually at a specific time and for backup and/or update purposes.

Verb:	EGRESS
Syntax:	(system) EGRESS from (location_A)
Like Verbs:	EXTRACT
Antonym:	INGRESS
Definition:	To translate (the entire telerobot) out of a surrounding (pressurizable or not) enclosure (location_A), including an airlock if desired.

Verb:	EXTEND
Syntax:	(subsystem) EXTEND (object_A) from (object_B)
Like Verbs:	INSERT
Antonym:	WITHDRAW
Definition:	To move an end effector (on a manipulator) and/or an object it contains (object A) from its current position in any direction away from the telerobot system's base (object B), with no specific path or endpoint, and without regard to collision avoidance or least-time trajectories.

Verb:	EXTRACT
Syntax:	(subsystem) EXTRACT (object_A) from (object_B)
Like Verbs:	WITHDRAW
Antonym:	INSERT
Definition:	To pull object out of, or to remove from inside of, another object.

Verb:	EXTRACT feature
Syntax:	(subsystem) EXTRACT feature (feature) from (object_A)
Like Verbs:	ACQUIRE
Antonym:	none
Definition:	To perform a sensing/perception algorithm that procures a 'feature' (edge or vertex) from an object.

Verb:	FILL
Syntax:	(subsystem) FILL (subsystem) [with (consumable)] [until (condition)]
Like Verbs:	PRESSURIZE
Antonym:	DRAIN
Definition:	To put consumable (fluid, gas, cryogen) into a reservoir, esp. fuel and coolant for spacecraft. Involves determining relative conditions between 'empty' and 'full', usually by means of in-place instrumentation.

Verb:	FIND
Syntax:	
Like Verbs:	ACQUIRE
Antonym:	none
Definition:	DELETED FROM V1.0

Verb:	FOLD
Syntax:	(system) FOLD (object_A)
Like Verbs:	
Antonym:	UNFOLD
Definition:	To bend or press a flexible object (e.g., a thermal blanket, cable, etc.) so that one part is over another; double up upon itself. NOTE: this is an EXTREMELY complex action for a telerobot to execute with ANY degree of autonomy; for the near future, we can assume it is done teleoperatively.

Verb:	FREEZE
Syntax:	(subsystem/system) FREEZE [(subsystem/system)]
Like Verbs:	PAUSE
Antonym:	none
Definition:	To immediately halt (stop) a subsystem's or system's motion by cutting command inputs, applying brakes, cutting power to or backdriving the joints, or a combination of these; optional syntax [ ] is for teleoperation (e.g., IV1 FREEZE RMS).

Verb:	GRAPPLE
Syntax:	(subsystem) GRAPPLE (object_A)
Like Verbs:	CAPTURE
Antonym:	RELEASE
Definition:	To close the snares on a cable-tension end effector, such as the Orbiter RMS, around a compatible (grapple) fixture or object, and then to retract the snares, in order to draw tight and snug the payload (to which the grapple fixture or object is attached) to that end effector (GRAPPLE = CAPTURE + RIGIDIZE). Usually a preprogrammed sequence initiated by analog or digital command.

Verb:	GRASP
Syntax:	(subsystem) GRASP (object_A)
Like Verbs:	CLOSE gripper
Antonym:	UNGRASP
Definition:	To close a multi-fingered (2 or more) end effector upon an object with force sufficient to eliminate relative motion between object and gripper; normally requiring extensive force-feedback and planning.

Verb:	GRIP
Syntax:	
Like Verbs:	
Antonym:	
Definition:	DELETED FROM V1.0

Verb:	HANDOVER
Syntax:	(system) HANDOVER (system/subsystem) to (system)
Like Verbs:	
Antonym:	none
Definition:	To pass physical control of a telerobotic system from one entity or facility to another (e.g., from ground station to Space Station IVA, from IVA to EVA, from Space Station to OMV, etc.).

Verb:	IDENTIFY
Syntax:	(subsystem) IDENTIFY [(feature) from] (object_A)
Like Verbs:	EXTRACT feature
Antonym:	none
Definition:	To recognize or to classify an unknown or unclassified object or feature (parameters) of an object.

Verb:	INDEX
Syntax:	(system) INDEX (system) to (subsystem)
Like Verbs:	CALIBRATE
Antonym:	none
Definition:	To designate a zero point in the relationship between a hand controller and a manipulator. This includes many types of hand controller/manipulator combinations. Reindexing is the process whereby the operator can move an end effector to a new, more comfortable position (often after a rest or after the hand controller has reached the end of its motion envelope) and start from that point as a new zero.

Verb:	INGRESS
Syntax:	(system) INGRESS into (location_A)
Like Verbs:	INSERT
Antonym:	EGRESS
Definition:	To translate (the entire telerobot) into a surrounding (pressurizable or not) enclosure (location_A), including an airlock if desired.

Verb:	INITIALIZE
Syntax:	(system) INITIALIZE (subsystem)
Like Verbs:	ACTIVATE
Antonym:	none
Definition:	To send set-up data to a subsystem in preparation for activity from rest, after power-up; therefore, implies ACTIVATE has taken place, may require an UPLOAD if a preprogrammed sequence is not used (as is customary). Common robotics parlance.

Verb:	INITIATE
Syntax:	(system) INITIATE (procedure)
Like Verbs:	RESUME
Antonym:	TERMINATE
Definition:	To begin or originate a sequence or procedure.

Verb:	INSERT
Syntax:	(subsystem) INSERT (object_A) into (object_B)
Like Verbs:	EXTEND
Antonym:	EXTRACT
Definition:	To place object inside of, or put into, another object

Verb:	INSPECT
Syntax:	(system) INSPECT (object_A) for (condition) [with (subsystem)]
Like Verbs:	TEST
Antonym:	none
Definition:	To non-destructively examine an object, with or without tools (sensors), to verify conformance to design or expectation.

Verb:	INSTALL
Syntax:	
Like Verbs:	
Antonym:	
Definition:	DELETED FROM V1.0

Verb:	LIMP
Syntax:	
Like Verbs:	
Antonym:	
Definition:	DELETED FROM V1.0

Verb:	LOAD
Syntax:	(system) LOAD (object_A) onto (container_A)
Like Verbs:	FILL
Antonym:	OFFLOAD
Definition:	To move an object onto a transport vehicle, or container (e.g., LOAD strut onto pallet); denotes placement on a complex surface rather than within an enclosure, as with INSERT.

Verb:	LOAD subsystem
Syntax:	
Like Verbs:	
Antonym:	
Definition:	DELETED FROM V1.0

Verb:	LOCATE
Syntax:	(system) LOCATE (object_A) in (reference_frame)
Like Verbs:	ACQUIRE
Antonym:	none
Definition:	To determine a sensed object's position with respect to a frame of reference (frequently the base of a manipulator); for non-contact sensed objects, this implies that an ACQUIRE primitive has already been completed.

Verb:	MATCH
Syntax:	(subsystem) MATCH (feature) to (data)
Like Verbs:	ANALYZE
Antonym:	none
Definition:	To find a correlation, by an unspecified algorithm, between a sensed feature(s) of an image, and an existing model in CAD or some other database.

Verb:	MATE
Syntax:	(system) MATE (object_A) to (object_B)
Like Verbs:	ATTACH
Antonym:	DEMATE
Definition:	To connect an umbilical (only) with its interface through complementary connectors.

Verb:	MONITOR
Syntax:	(system) MONITOR (process/subsystem)
Like Verbs:	
Antonym:	none
Definition:	To watch, or observe a system, operation, or process of a machine through feedback and display of sensed data or return values from a computational or sequential execution.

Verb:	MOVE
Syntax:	(system) MOVE (object_A) (condition) [(direction)] [to
Like Verbs:	MOVE along
Antonym:	none
Definition:	To change the position of an end effector and/or an object it contains in a given direction or to a specific point with respect to some reference frame; conditions may be assigned, i.e. direct, free, guarded, constrained, gross, fine, etc.

Verb:	MOVE along
Syntax:	(system) MOVE (object_A) along (feature) [with (condition)]
Like Verbs:	MOVE
Antonym:	none
Definition:	To change the position of an end effector and/or an object it contains with respect to a reference frame resolved to the base of the telerobot ALONG (conforming the motion to) a specified feature (path, edge, or surface) of an object being sensed, WITH conditions [optional] that are assigned to the motion from a menu that may include a type of motion (guarded, constrained, gross, fine, collision avoidance, etc. or a combination); implies that a 'MOVE until' has already been successfully executed.

Verb:	MOVE to
Syntax:	
Like Verbs:	MOVE
Antonym:	none
Definition:	DELETED FROM V1.0

Verb:	MOVE until
Syntax:	(system) MOVE (object_A) (direction) until (force/torque) [with
Like Verbs:	MOVE
Antonym:	none
Definition:	To change the position of an end effector and/or an object it contains with respect to a reference frame resolved to the base of the telerobot UNTIL a specified force against the telerobot's frame is sensed, WITH conditions [optional] that are assigned to the motion from a menu that may include type of motion (guarded, constrained, gross, fine, collision avoidance, etc., or a combination).

Verb:	MOVE while
Syntax:	(system) MOVE (object_A) (direction) while (force/torque) [with
Like Verbs:	MOVE
Antonym:	none
Definition:	To change the position of an end effector and/or an object it contains with respect to a reference frame resolved to the base of the telerobot WHILE a specified force against the telerobot's frame is sensed (normally to follow a surface or edge via force feedback), WITH conditions [optional] that are assigned to the motion from a menu that may include type of motion (guarded, constrained, gross, fine, collision avoidance, etc., or a combination); implies that a 'MOVE until' has already been successfully executed.

Verb:	OBSERVE
Syntax:	
Like Verbs:	
Antonym:	
Definition:	DELETED FROM V1.0

Verb:	OFFLOAD
Syntax:	(system) OFFLOAD (object_A) from (container_A) to (location_A)
Like Verbs:	EXTRACT
Antonym:	LOAD
Definition:	To move an object from a transport vehicle, or container (e.g., OFFLOAD strut onto pallet); denotes placement on a complex surface rather than within an enclosure, as with EXTRACT.

Verb:	OPEN
Syntax:	(system) OPEN (object_A)
Like Verbs:	
Antonym:	CLOSE
Definition:	To make an enclosure accessible from without, or free throughput in a channel, by removing obstruction(s) to the path of access for objects or material (i.e., applies to doors and valves).

Verb:	OPEN gripper
Syntax:	(system) OPEN gripper (subsystem) [to (force)] [to (separation)]
Like Verbs:	RELEASE
Antonym:	CLOSE gripper
Definition:	To move the touch pads on fingers of a multi-fingered end effector farther apart to a specified separation or feedback force; does not imply that the gripper is or is not grasping an object.

Verb:	ORIENT
Syntax:	
Like Verbs:	
Antonym:	
Definition:	DELETED FROM V1.0

Verb:	PAN
Syntax:	(subsystem) PAN (subsystem) (direction) [(number) degrees]
Like Verbs:	ALIGN
Antonym:	none
Definition:	To orient a resource (usually a sensor, e.g., video camera, still camera, laser rangefinder, etc.) positively or negatively in azimuth (yaw).

Verb:	PAUSE
Syntax:	(system) PAUSE [(procedure)] [on (condition)]
Like Verbs:	FREEZE
Antonym:	RESUME
Definition:	To interrupt a sequence or procedure, while retaining any interim values generated so as to recycle the procedure from its interrupt point if RESUMEd. Since activity is assume if PAUSE is used, the procedure is optional as long as the system being interrupted is specified.

Verb:	POSITION
Syntax:	
Like Verbs:	
Antonym:	
Definition:	DELETED FROM V1.0

Verb:	POWER
Syntax:	(subsystem) POWER (subsystem) (on/off)
Like Verbs:	ACTIVATE
Antonym:	implicit
Definition:	To turn power (on/off) to the manipulator itself.

Verb:	PRESSURIZE
Syntax:	(system) PRESSURIZE (object_A) [with (subsystem)]
Like Verbs:	FILL
Antonym:	PURGE
Definition:	To introduce fluids into a fluid transfer umbilical after mating but prior to use for FILL or DRAIN activities.

Verb:	PURGE
Syntax:	(subsystem) PURGE (subsystem) [via (subsystem)] [with consumable)]
Like Verbs:	DRAIN
Antonym:	PRESSURIZE
Definition:	To empty or flush (usually via a nonreactive substance, such as an inert gas) fluids from a fluid transfer umbilical prior to demating.

Verb:	RANGE
Syntax:	(system) RANGE (object_A) to (feature/object_B) via (subsystem)
Like Verbs:	LOCATE
Antonym:	none
Definition:	To determine straight-line distance from one object or feature to another; may involve active or passive sensing (and) algorithms for converting range from sensor to range from resolution point (object B, usually an interface or tool).

Verb:	RELEASE
Syntax:	(subsystem) RELEASE (object_A)
Like Verbs:	OPEN gripper
Antonym:	CAPTURE
Definition:	To remove from confinement, to free from restraint; also, to open the snares on an enveloping end effector (such as the RMS) or a dedicated mechanism (such as a latch). Normally a preprogrammed action requiring no planning.

Verb:	REMOVE
Syntax:	
Like Verbs:	
Antonym:	
Definition:	DELETED FROM V1.0

Verb:	REPLENISH
Syntax:	
Like Verbs:	
Antonym:	
Definition:	DELETED FROM V1.0

Verb:	RESUME
Syntax:	(system) RESUME [(procedure)]
Like Verbs:	INITIATE
Antonym:	PAUSE
Definition:	To continue a sequence or procedure after a PAUSE, using any interim values previously generated to recycle the procedure from its interrupt point. Since activity is assume if PAUSE is used, the procedure is optional as long as the system being interrupted is specified.

Verb:	RETRACT
Syntax:	(system) RETRACT (system/subsystem)
Like Verbs:	STOW
Antonym:	DEPLOY
Definition:	To move a mechanical appendage (e.g., a manipulator, an antenna boom, etc.) out of its operational configuration.

Verb:	RETRIEVE
Syntax:	
Like Verbs:	
Antonym:	
Definition:	DELETED FROM V1.0

Verb:	RIGIDIZE
Syntax:	(system) RIGIDIZE (subsystem)
Like Verbs:	CAPTURE
Antonym:	DERIGIDIZE
Definition:	To retract the snares of a cable-tension end effector, such as the Orbiter RMS, usually after enveloping a compatible grapple fixture or object, in order to draw tight and snug the payload (to which the grapple fixture or object is attached) to that end effector.

Verb:	ROTATE
Syntax:	
Like Verbs:	
Antonym:	
Definition:	DELETED FROM V1.0

Verb:	SCHEDULE
Syntax:	(subsystem) SCHEDULE (procedure) [for (system)]
Like Verbs:	
Antonym:	none
Definition:	To plan or list the start/stop time (duration) and sequence of an operation in relation to other operations.

Verb:	SCREW
Syntax:	(subsystem) SCREW (object_A) (in/out) [(number) degrees] [with
Like Verbs:	ATTACH
Antonym:	implicit
Definition:	To turn a threaded fastener, usually in a threaded slot, either one of two directions, the interpretation of which depends on knowledge of the thread convention used (right-hand or left-hand). Implies a previously successful ATTACH. Does not imply a method; could be with a power tool, or with a manual tool and some number of joints of the manipulator gripping it, etc. This syntax allows for both SCREW and UNSCREW; therefore, the antonym is implicit. Only verbs alike in concept to the positive activity are listed under "like verbs".

Verb:	SELECT mode
Syntax:	(subsystem) SELECT mode (mode)
Like Verbs:	CONFIGURE
Antonym:	none
Definition:	To select a control mode for the telerobot before beginning an operation, either through operator action, or machine planning. Options on (mode) include position, pose, path, velocity, shared, force feedback, compliant, single-arm, dual-arm, or combinations of the above.

Verb:	SELECT resource
Syntax:	(subsystem) SELECT resource (subsytem)
Like Verbs:	CONFIGURE
Antonym:	
Definition:	To select a resource for the telerobot, normally during operations, in order to enhance operator interface with the task. Options on (resource) include camera, light, sensor, communications channel, etc., and combinations of the above. This primitive is normally associated with commands sent from the operator interface, but might be encountered by an intelligent telerobot selecting its own resources for a subtask.

Verb:	SLIDE
Syntax:	
Like Verbs:	
Antonym:	
Definition:	DELETED FROM V1.0

Verb:	SPECIFY
Syntax:	
Like Verbs:	
Antonym:	
Definition:	DELETED FROM V1.0

Verb:	SQUEEZE
Syntax:	(subsystem) SQUEEZE (object_A) until (force)
Like Verbs:	CLOSE gripper
Antonym:	none
Definition:	To close the fingers of a multi-fingered (2 or more) end effector upon an already-grasped object with a specified force.

Verb:	STABILIZE
Syntax:	(system) STABILIZE (object_A/system)
Like Verbs:	ALIGN
Antonym:	none
Definition:	To allow the innate stiffness matrix of one (or more) manipulator(s) to dampen or eliminate motion of a grasped or grappled object about all of its axes.

Verb:	STOP
Syntax:	(system) STOP (system) on (condition)
Like Verbs:	FREEZE
Antonym:	none
Definition:	To normally halt a subsystem's or system's motion by canceling execution of a motion command upon encountering a given condition (position, force, torque, or a combination); distinct from FREEZE, which is a contingency action.

Verb:	STOW
Syntax:	(system) STOW (object_A) in (location_A)
Like Verbs:	RETRACT
Antonym:	UNSTOW
Definition:	To return a mechanical appendage or manipulator arm to a configuration (with respect to its support systems) allowing it to be secured to the structure supporting its base.

Verb:	TERMINATE
Syntax:	(system) TERMINATE (procedure)
Like Verbs:	FREEZE
Antonym:	INITIATE
Definition:	To end a sequence or procedure, zeroing any interim values so as to recycle the procedure from its beginning if INITIATEd again.

Verb:	TEST
Syntax:	(system) TEST (object_A/procedure) [with (condition)]
Like Verbs:	INSPECT
Antonym:	none
Definition:	To determine or to verify operational quality or quantity of an object or procedure through execution of a prescribed sequence of events; may involve comparison against a control value (norm) or independent recording of results without analysis.

Verb:	TILT
Syntax:	(subsystem) TILT (subsystem) (direction) [(number) degrees]
Like Verbs:	ALIGN
Antonym:	none
Definition:	To orient a resource (usually a sensor, e.g., video camera, still camera, laser rangefinder, etc.) positively or negatively in elevation (pitch).

Verb:	TOP-OFF
Syntax:	
Like Verbs:	
Antonym:	
Definition:	DELETED FROM V1.0

Verb:	TOUCH
Syntax:	(system) TOUCH (object_A) to (object_B) [with (condition)]
Like Verbs:	MOVE until
Antonym:	
Definition:	To effect contact of a point to a surface, especially a tool tip or finger on a multi-fingered hand.

Verb:	TRACK
Syntax:	(subsystem) TRACK (object_A) [with (subsystem)]
Like Verbs:	LOCATE
Antonym:	none
Definition:	To observe or record (at discrete intervals) the path or trajectory of an object that is (usually) moving with respect to the telerobot base, with mechanical (joint/link/sensor motion analysis) or sensory (contact or non contact) systems.

Verb:	TRANSFER
Syntax:	(subsystem) TRANSFER (consumable) to (subsystem)
Like Verbs:	DRAIN
Antonym:	none
Definition:	To pump fluid or gas from one container to another; unlike FILL, does not involve determining relative conditions between "empty" and "full".

Verb:	TRANSLATE
Syntax:	(system) TRANSLATE [(system)] to (location_A)
Like Verbs:	TRANSPORT
Antonym:	none
Definition:	To reposition the entire telerobot; analogous to what a human does during an EVA translation. For objects moved by the action, see TRANSPORT.

Verb:	TRANSMIT
Syntax:	(system) TRANSMIT (data) to (system)
Like Verbs:	DOWNLOAD
Antonym:	none
Definition:	To send data via electromagnetic radiation (e.g., radio waves, microwaves, etc.); may imply voice communication between teleoperator and telerobot.

Verb:	TRANSPORT
Syntax:	(system) TRANSPORT (object_A) from (location_A) to (location_B)
Like Verbs:	TRANSFER
Antonym:	
Definition:	To carry an object grasped by a telerobot from one location to another location by repositioning the base of the telerobot (see TRANSLATE); to move a grasped object via translation of the telerobot, i.e. implies TRANSLATE.

Verb:	TURN
Syntax:	
Like Verbs:	
Antonym:	
Definition:	DELETED FROM V1.0

Verb:	UNBERTH
Syntax:	(system) UNBERTH (vehicle)
Like Verbs:	DETACH
Antonym:	BERTH
Definition:	To remove, using a manipulator arm, a vehicle (spacecraft) from a positioning and/or retention system equipped with a fixture specifically for that purpose.

Verb:	UNDOCK
Syntax:	
Like Verbs:	
Antonym:	DOCK
Definition:	DELETED FROM V1.0

Verb:	UNFOLD
Syntax:	(system) UNFOLD (object_A)
Like Verbs:	
Antonym:	FOLD
Definition:	To bend or pull a flexible object (e.g., a thermal blanket, cable, etc.) so that one part previously covering another is removed, exposing the covered section. NOTE: this is an EXTREMELY complex action for a telerobot to execute with ANY degree of autonomy; for the near future, we can assume it is done teleoperatively.

Verb:	UNGRASP
Syntax:	(subsystem) UNGRASP (object_A)
Like Verbs:	OPEN gripper
Antonym:	GRASP
Definition:	To free an object from a multi-fingered end effector, allowing relative motion between the two; normally requiring much less planning than GRASP.

Verb:	UNSCREW
Syntax:	
Like Verbs:	
Antonym:	
Definition:	DELETED FROM V1.0

Verb:	UNSTOW
Syntax:	(system) UNSTOW (subsystem) [from (subsystem)]
Like Verbs:	DEPLOY
Antonym:	STOW
Definition:	To move a mechanical appendage or manipulator arm to a configuration (with respect to its support systems) preventing it from being secured to the structure supporting its base (after release from those devices) and freeing it for further motion, as desired.

Verb:	UPDATE
Syntax:	(subsystem) UPDATE (data) from (subsystem)
Like Verbs:	DOWNLOAD
Antonym:	none
Definition:	To modify a real or computed state vector or world model with newer information received from a source outside the telerobotic system.

Verb:	UPLOAD
Syntax:	(subsystem) UPLOAD (data) to (subsystem)
Like Verbs:	TRANSMIT
Antonym:	DOWNLOAD
Definition:	To transfer software or data from a receiving computer system to an actuating (requesting) computing subsystem, e.g., from an on-orbit telerobot system computer to a ground system, or to another on-orbit spacecraft or system.

Verb:	VERIFY
Syntax:	(subsystem) VERIFY (object_A/system/subsystem/procedure) (condition)
Like Verbs:	IDENTIFY
Antonym:	none
Definition:	To determine the truth or correctness of a condition of an object, system, subsystem, or procedure.

Verb:	WITHDRAW
Syntax:	(subsystem) WITHDRAW (object_A) from (object_B)
Like Verbs:	EXTRACT
Antonym:	EXTEND
Definition:	To move an end effector (on a manipulator) and/or an object it contains (object A) from its current position in any direction back toward the telerobot system's base (object B), with no specific path or endpoint, and without regard to collision avoidance or least-time trajectories.

SECTION VI

TEJAS VERSION 1.0 USER'S MINIGUIDE: TEJASHOME, EVAPRIMITIVES, AND TELEPRIMITIVES STACKS

A. BACKGROUND

The crew-EVA and telerobot generic primitives lists in the previous Sections III-B and III-C are also available in two interactive hypermedia stacks (files) called EVAPrimitives and TelePrimitives. These stacks were created using the Apple HyperCard(c) programming utility on the Apple Macintosh personal computer. The stacks are provided on the 3.5" floppy disk contained in this report. Also on that disk are the TEJASHome, TEJAS Help and Open Me First!! stacks. The EVAPrimitives and TelePrimitives reference stacks form an electronic database that is inherently more useful than the printed version for task analysis and specific applications. The stacks can be installed immediately and used on any Macintosh personal computer by following the instructions in the TEJAS User's Miniguide (see "How to Install TEJAS" and the "TEJAS Setup Card," pages 6-27).

It should be noted that the TEJAS User's Miniguide was designed as an addition to this report and, as such, contains a double numbering system. Page numbers designated 6-x refer to the report page numbers (at the bottom of page). Numbers designated x.x refer to the TEJAS User's Miniguide page numbers (at the upper-right margin of each card).

When used with the complete TEJAS Version 1.0 stack set, the EVAPrimitives and TelePrimitives stacks serve as interrelated, standardized libraries of generic crew-EVA and telerobot primitives provided by the task analysis community, using a common generic syntax structure for each generic primitive.

The complete TEJAS Version 1.0 Overview (Figure 6-1) is a "road map" that shows the organization of the stack system. Analysis stacks (diamond "work sign" icons) draw on information in the Reference stacks (cube and octagon icons) are part of a rapid point-and-click utility for building scripts of specific task primitives (filled-in cube icons) and for any EVA or telerobotics task. It is in the specific primitives list for each task that the correlation between EVA and telerobotics must be drawn. Standardizing the list of generic EVA and telerobot primitives in the EVAPrimitives and TelePrimitives stacks is a prerequisite to achieving that correlation.

B. USING THE TELEPRIMITIVES AND EVAPRIMITIVES STACKS

These stacks are meant to be interactive and can be used with any database system running on a Macintosh, including spreadsheets, relational databases, word-processed reports, and hypermedia utilities. Used either individually, or combined with the other TEJAS stacks, these hypermedia files constitute a tool for the task analysis community. Hypermedia software manages volumes of data and provides a means for communicating complex ideas, relationships, and processes inherent to task planning. The TEJAS User's Miniguide provides the background of primitives development, but

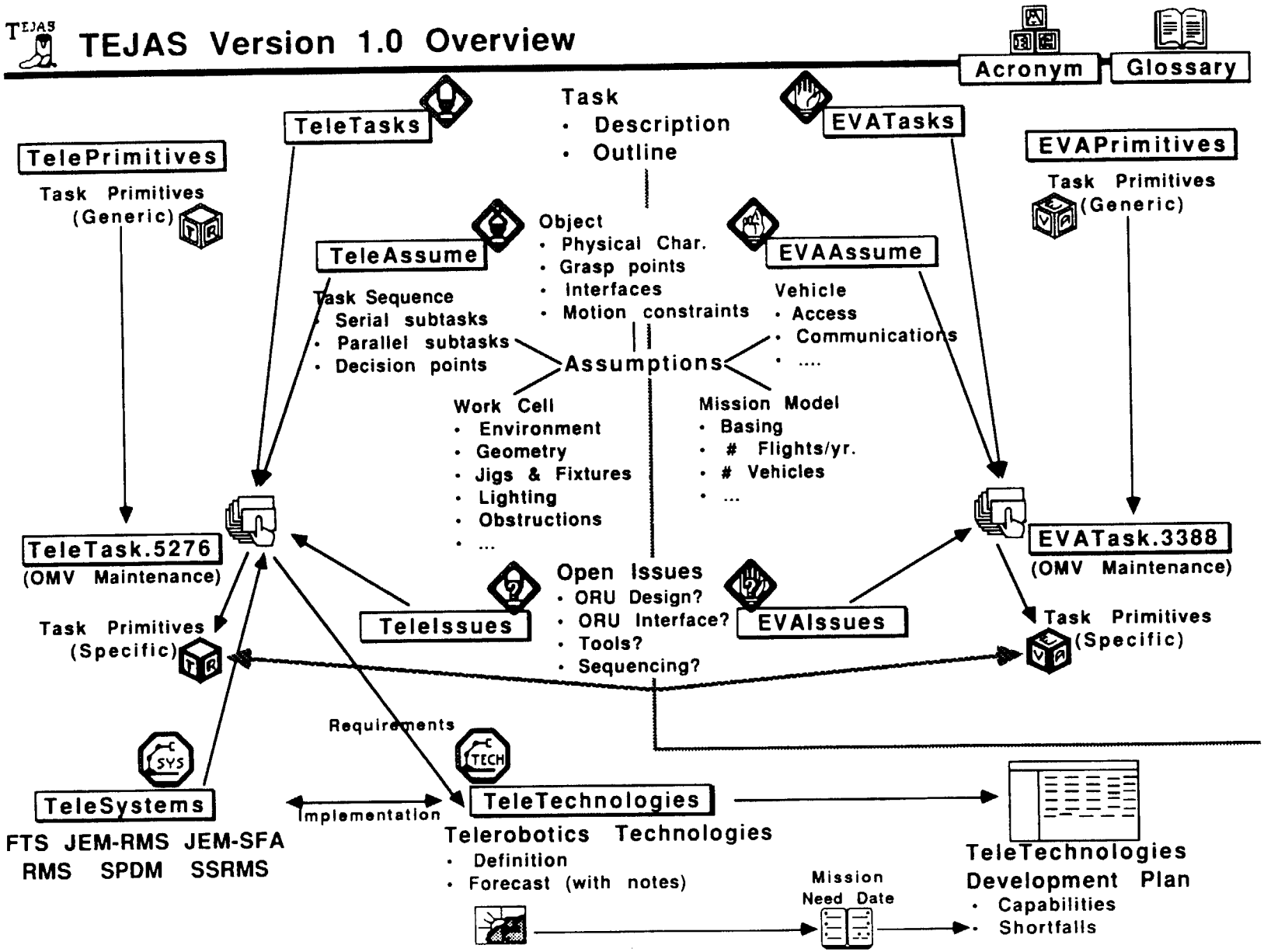


Figure 6-1. TEJAS Overview

their usage depends on the members of the EVA and telerobot task analysis community.

The generic primitives stacks result from a first compilation of task primitives taken from a variety of sources; these primitives are then discussed and analyzed for a second integration (see "Task Primitives Development," Help section 7.4.7 or 7.5.7, pages 6-73 or 6-92). With the current release, it is hoped that the revision cycle for the next update can be shortened. These stacks should be used to communicate with other analysts and with the TEJAS Editor. There are four simple rules to follow: (1) Use the stacks internally, (2) Make comments and/or changes, (3) Send the changed stacks (NOT a printout) to the TEJAS Editor, and (4) Identify other potential users for the TEJAS Editor.

(1) How to Use the Stacks

After installing the stacks onto the hard-disk drive by following the "How to Install TEJAS" instructions in this TEJAS User's Miniguide (Help section 3.5, page 6-27), open either the EVAPrimitives or TelePrimitives stack. Specific instructions should be read for that stack in "The User's Role" section of the TEJAS User's Miniguide (see Help section 4.11, page 6-39 and the stack-specific Menu Cards, pages 6-60, 6-68, and 6-87). All Help cards printed in the TEJAS User's Miniguide are part of an abbreviated TEJAS Help stack and are available online (i.e., from a pop-up menu). "How to Use TEJAS Help" and "The TEJAS User's Guide," Help Sections 3.6 and 3.7, pages 6-28 to 6-30 are suggested reading.

The cards can be paged through by using the Previous and Next buttons (the left and right arrows at the bottom center of all cards). The remaining buttons and menus (explained in the Help stack/TEJAS User's Miniguide) should be tried. The definitions, syntax, and (if desired) the history for each generic primitive should be read. Comparing them with previous experience is suggested (note that these are generic, not specific primitives; this report explains the difference). Missing primitives should be checked and noted.

(2) How to Change the Stacks

Enter questions, observations, or ideas in the User Notes field. The User Notes field can be opened by pressing the notepad button marked *User* (at the bottom right of every card; see "TEJAS Common User Notes field," Help section 6.5, page 6-58). Comments can be typed in. The User Notes field can be used at any time while working in the stacks.

The content of the fields can be changed, as they are not locked. However, there are certain rules to follow. Specific instructions for individual stacks are located in "Changing the Standard," "Adding Cards," and "Deleting Cards" Help sections (see the stack-specific Menu Cards, pages 6-60, 6-68 and 6-87).

Important: DO NOT change the "names" of any stacks, backgrounds, or cards.

Further details on how to transfer information into and out of TEJAS are given in "Input and Output," Help section 5.0, pages 6-41 to 6-45.

(3) How to Communicate Your Changes

Once a set of comments and/or changes has been compiled, the stacks should be copied onto a floppy diskette and sent to the TEJAS Editor. Each comment and change will be reviewed. HyperTalk will append that text to the History field for each primitive. If changes have been made to the cards themselves or if cards have been added, those changes will also be reviewed.

The resolution of all proposed changes will be documented under Version 2.0 FINAL NOTES in the History field for traceability. All changes sent in by July 28, 1990, will be incorporated in the TEJAS Version 2.0 release scheduled for the end of FY90. If a significant volume of feedback is received prior to the deadline; an interim revision may be released.

These stacks can be expanded without limitations. New features, such as 2-D video "clips" to demonstrate the verbs, better navigation aids, and any number of hierarchical categorization systems can be added if so desired. Please advise the TEJAS Editor of any operational errors or spelling errors and comment on the way the stacks work, look, or are organized. Ideas on improvements and new fields are welcome.

Feedback on content, organization, and interface is essential in order to develop a dynamic resource that will reflect the task analysis community's needs. Wide application of this community resource will result in clearer understanding and better communication among crew-EVA and telerobot operations.

C. ABOUT THE TEJAS USER'S MINIGUIDE

This TEJAS User's Miniguide is a subset of the complete TEJAS Version 1.0 User's Guide (see Figure 6-2 and "The TEJAS User's Guide," Help section 3.7, page 6-30). The TEJAS User's Miniguide includes the same general information about TEJAS but also includes detailed, stack-specific information about the TelePrimitives, EVAPrimitives, and TEJASHome stacks on disks (Help sections 7.1, 7.4 and 7.5). Detailed information on the other TEJAS Version 1.0 stacks is not included (see the "TEJAS Help Menu," pages 6-10 to 6-12).

Both the full TEJAS User's Guide and the TEJAS User's Miniguide are printed copies of the TEJAS Help stack, interspersed with example cards from the stacks covered. When accessing TEJAS Help from within any TEJAS stacks, the Help cards will appear on the screen. The TEJAS Help stack can be entered directly from the desktop, from the pop-up menu attached to the 'TEJAS boot' button (see "TEJAS Common Navigation and Action Buttons," Help section 6.2, pages 6-50 to 6-56), or from the 'TEJAS Help' button in the middle of the TEJASHome card (see Help section 7.1.8, page 6-64).

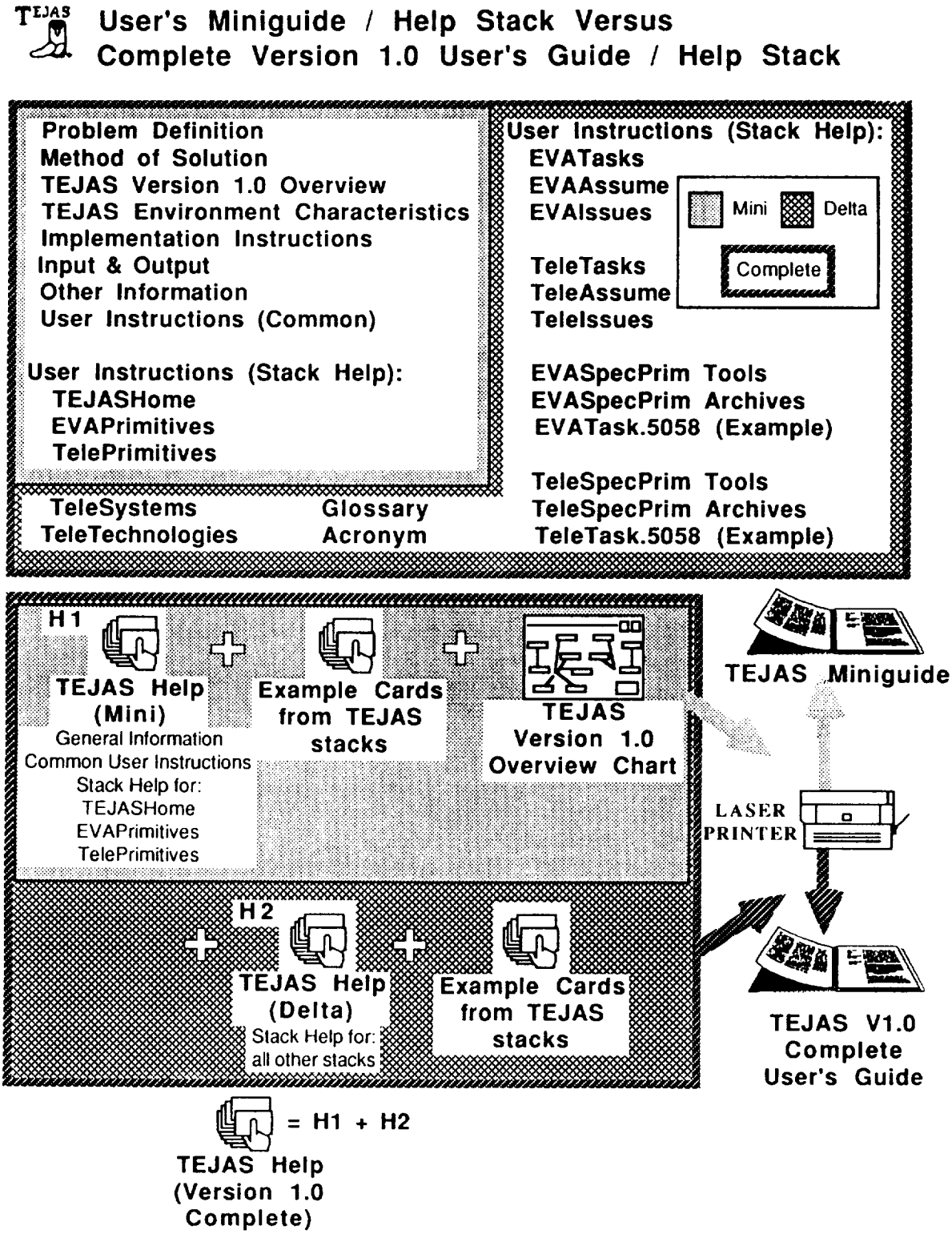


Figure 6-2. TEJAS Structure Showing User's Miniguide Versus Complete System

D. OBTAINING COPIES OF TEJAS VERSION 1.0

Anyone may obtain copies of the TEJAS Version 1.0 stacks by contacting the TEJAS Editor. For FY 1990, the TEJAS Editor is

Michael L. Drews
Jet Propulsion Laboratory
Mail Stop 303-308
4800 Oak Grove Drive
Pasadena, CA 91109

Please send one blank, unformatted 800K 3.5" floppy disk for the EVAPrimitives (generic crew-EVA primitives) and TelePrimitives (generic telerobot primitives) stacks or four blank disks for the entire TEJAS Version 1.0 stack system. With the complete TEJAS Version 1.0 stack system, a copy of the complete TEJAS User's Guide will be included with a cover letter.

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Telerobotics/EVA Joint Analysis System (TEJAS):

A Standardized Multimedia Database and Analysis Tool for EVA and Telerobotics

Version 1.0 User's Miniguide: TEJASHome, EVAPrimitives and TelePrimitives Stacks

Michael Drews
March 30, 1990

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INSTRUCTIONS:
Click ☐ box to access section;
Click arrows to page through Help stack;
Click 'T-flag' to return to point of origin.

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INSTRUCTIONS:
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Click arrows to page through Help stack;
Click 'T-flag' to return to point of origin.

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Click ☐ box to access section;
Click arrows to page through Help stack;
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☒= Not Available in Version 1.0 Help Stacks

INSTRUCTIONS:
Click ☐ box to access section;
Click arrows to page through Help stack;
Click 'T-flag' to return to point of origin.

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▨= Not Available in Version 1.0 Help Stacks

INSTRUCTIONS:
Click ☐ box to access section;
Click arrows to page through Help stack;
Click 'T-flag' to return to point of origin.

TEJAS V1.0 | 3/30/90 | Help Menu

Define USER...

Section 1.0

Problem Definition

Telerobotics Technologies Development Planning 1.1 1 of 2

The Telerobotics/EVA Joint Analysis System (TEJAS) project was initiated by the NASA Office of Space Station (Code ST) in response to an urgent perceived need for a high-level mechanism to plan the development of telerobotics technologies based on a realistic understanding of

- technologies required to perform on-orbit tasks,
- planned telerobotic systems' use of those technologies, and
- the forecast for each technology in terms of time and money, versus the need date for on-orbit test or deployment.

With this information available, a set of relational rules could be constructed that would define the critical path of technological development, and help to prioritize the expenditure of time and money. However, the information was not available, nor was any repeatable, logical method or tool in place to assimilate, access, or derive this data.

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Telerobotics Technologies Development Planning 1.1 2 of 2

As a further dimension to the problem, the relationships between telerobotics and EVA were not well established, although they are causally implicit: Telerobotics technology requirements derive from a need to support crew-EVA with telerobots that help to perform an on-orbit task under specific circumstances. Crew-EVA involves humans using tested and proven equipment and checklists, based on an established, evolving, and integrated set of technologies and proven task analysis and scripting techniques. Telerobot work systems will be composed of hardware and software resulting from technology development in related fields. These fields are not yet integrated, nor is the task scripting fully evolved. The working premise was that relationally linking EVA and telerobotics at various levels would help to solve both of these interrelated shortcomings.

Keeping track of this data requires an extensive database of technologies, telerobot work systems, task primitives, tools, etc. that exists separately in paper and electronic documents. The first step of TEJAS was to compile it.

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Telerobotics/EVA Relationship Problem

- Clear, consistent, repetitive, interactive and exchangeable method of relating EVA and telerobotics is needed on various levels:
  - Activity: Task, Subtask, Primitives
  - Environment
    - On-orbit astrophysical medium
    - Worksites and taskboards
  - External resources
    - Tools and services, jigs etc.
  - Work Systems
    - FTS, JEMS-RMS, JEMS-SFA, RMS, SPDM, SSRMS
  - Technologies
    - Sensing/Perception
    - Planning/Reasoning
    - Control/Execution
    - Operator Interface
    - System Architecture

} FY 1989 Emphasis

Section 2.0

Method of Solution

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TEJAS Objectives

- Create a multimedia technology development planning tool for telerobotics that gives definitive direction for the technology push NASA will have to make to get space telerobots working. Make that tool
  - Powerful, fast, and complete
  - Compatible with the widest range of centers and corporations
  - User-friendly; almost no training required
  - Flexible; WORKS the way the user THINKS, not vice versa
  - Adaptable; can change with changing requirements or can use different methodologies, depending on the user's wants
  - Expansible; easily accommodates revisions and additions
  - Self-referencing; provides complete traceability to sources

- Use that tool to
  - Determine technology requirements for any specific task
  - Show how six telerobot work systems match those requirements
  - Build a concrete relationship between crew-EVA and telerobotics

What Is TEJAS?

TEJAS is...

- an information system of related multimedia data

- a task analysis tool for EVA and Telerobotics that can form relational links between the two fields for any task through their task primitives

- a technology development planning tool for Telerobotics that can give definitive direction for the needed technology push

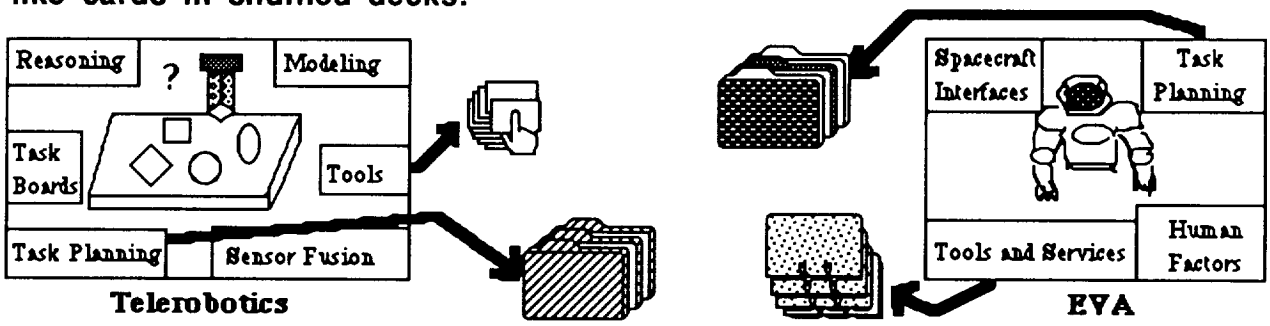
- a software-based reference for EVA and Telerobotics

- a set of hypermedia stacks that can be used individually, collectively, or card-by-card in many other applications

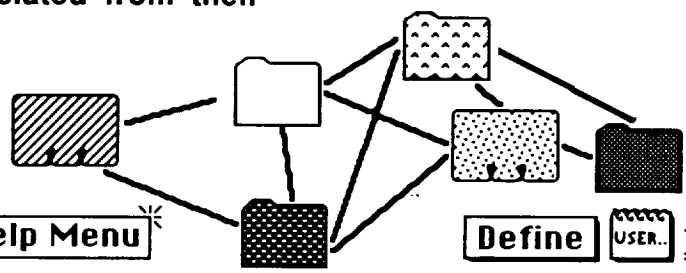
...built within an object-oriented programming environment that comes FREE with and runs on any Macintosh personal computer (≥1 Mbyte RAM)

TEJAS Basic Approach

TEJAS is an object-oriented programming environment, in which elemental research components such as task primitives and technologies, are treated like cards in shuffled decks:



The cards can be disassociated from their traditional groupings and related freely using the TEJAS scripts.



Elemental Components of Research

Every area of research breaks down eventually into some set of elemental components. Many lists of components, arranged in multiple categorization schemes, have been generated by people at different research centers as databases, spreadsheets, CAD files, and especially written documents.

If you could deal effectively not just with lists but also with individual components, you could create a 'master list' of cards of different forms, each a self-contained, multimedia database element containing one telerobotics component that every researcher could use or not use as they saw fit. You could combine and link these cards in many different ways: computationally, conceptually, chronologically, causally, etc. This would allow researchers to exchange (a) basic knowledge, such as terms, descriptions of tools etc., and (b) their ideas, represented by linked stacks of cards showing the reasons for the links.

The search for a software tool that could do all this led to hypermedia.

Hypermedia Rationale

For hypermedia to perform complex, multidisciplinary telerobotics/EVA relationships and technology development planning, it must be

- Multifaceted - including
  - Database functions: store, retrieve, copy, delete, update, link, search, and sort (by various criteria) in MULTIPLE MEDIA, including numbers, text, formulae, charts and graphs, drawings, even scanned documents
  - Spreadsheet functions: do calculations, macros, charts and graphs
  - Expert system functions (limited): have built-in ability to document and show thought processes leading to specific conclusions, without the use of a dedicated Artificial Intelligence software shell or microprocessor

- Fast - run on every applicable system without long delays
- Expandable - unlimited file size, with no change in speed
- Customizable - able to retain core data and functions and still be adaptable to a particular user's needs

More--->

TEJAS V1.0 3/30/90 Help Menu Define USER..

Hypermedia Rationale cont'd

Hypermedia must also be

- System-friendly - work interactively with existing database tools without modification or rehosting

- User-friendly - accessible via several layers of expertise:
  - Novice: no programming/user skills; intuitive (no training, no manuals required) viewing of information, analysis methods, and underlying thoughts through a GRAPHICAL, menu-driven interface
  - User: able to operate tool fully without modification
  - Superuser: able to modify certain steps and create new processes without deleting or distorting the source code
  - Programmer: able to access and customize source code

- Accessible – Inexpensive and available to every researcher wishing to exchange information with others in the telerobotics and EVA fields

TEJAS V1.0 3/30/90 Help Menu Define USER..

HyperCard Selection Rationale

• HyperCard is a user-customizable programming utility with which you can create tools that work the way you think. Half multimedia database and half programming tool, it incorporates most of the multimedia functions required for research and analysis in EVA and telerobotics.

• HyperCard files – called 'stacks' – and individual items in each stack – called 'cards' – can be linked together for calculation, thought association, graphing, searching, sorting, etc. in almost unlimited ways. The infinitely customizable stack format is always compatible with any other card or stack, regardless of origin.

• Traditional uses of HyperCard include demonstration and training stacks for software programs, archival stacks for museums and graphics artists, and office information tools for business. TEJAS is one of the more advanced scientific applications in HyperCard.

Section 3.0

Before You Begin

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What You Should Know About HyperCard...

TEJAS has been designed for users with minimal knowledge of HyperCard. The TEJAS Help stack (printed with examples as the TEJAS User's Guide) tells you how to use TEJAS. But it helps to know a little of the HyperCard terminology and basic concepts.

Apple Computer, Inc. provides two resources with HyperCard to help you:
1. The "HyperCard User's Guide" – the printed manual
2. The 'Help', 'Help Index', and 'Help Samples' stacks for HyperCard, accessed jointly through the 'Help' item from the 'Go' menu visible at the topmost menubar anytime any stack is open. The HyperCard Help stacks are brief explanations of every term, command, and button in HyperCard, while the manual is much more in-depth in both explanation and examples.

For optimum first use of TEJAS, read the Preface and Chapters 1 and 2 of the "HyperCard User's Guide." Using the stack-based Intro in the Help stack will introduce you to basic concepts. Try it!

What TEJAS Assumes...

TEJAS assumes that

- You are using an Apple Macintosh computer with a hard disk drive (for RAM and drive size requirements, see Help section 3.3).

- You are familiar with basic Macintosh terminology (e.g., mouse, clicking, dragging, selecting, highlighting, files, folders, windows, etc.).

- You have installed HyperCard and its attendant stacks on your Macintosh.

- You own or have access to the documentation that came with the HyperCard application (see 'What You Should Know About HyperCard,' Help section 3.1).

When appropriate, these TEJAS Help stack cards will refer you to the "HyperCard User's Guide" for further explanations.

What You Need to Run TEJAS: Hardware

TEJAS will run on any Apple Macintosh personal computer with AT LEAST:

- 1 megabyte (Mbyte) of RAM (2-4 is preferred)
- An 800K floppy disk drive (input) and 2-3 megabytes of hard disk space

HyperCard stacks and HyperTalk scripts have no size limitations. As with any program, it is still up to the designer to make efficient use of RAM. However, stacks up to 3 Mbytes have been built that run on a Macintosh SE with no added delays. As long as the ROM drive is large enough to hold the stack, it will run.

TEJAS will NOT run on DOS-based machines because the system that makes HyperCard's operation possible is incompatible with DOS. However, TEJAS stacks can work with DOS-based files, using a DOS interface board or PC-emulating software in your Macintosh.

More --->

TEJAS V1.0 | 3/30/90 | Help Menu | Define USER...

What You Need to Run TEJAS: Hardware cont'd

TEJAS was developed to run quickly and efficiently on a Macintosh SE (Motorola 68000 processor), with 2 megabytes of RAM and a 20 megabyte internal hard disk.

The faster the hard disk drive (ROM drive) on which the TEJAS stacks are stored, the faster the stack system will run. Tested drives' seek times were from 52 milliseconds (relatively slow) to 28 milliseconds (moderately fast).

With 3 Mbytes of RAM, TEJAS runs noticeably faster on any processor.

With 4 Mbytes of RAM, TEJAS can run under Multifinder with other large applications simultaneously (or without other applications with 2 Mbytes).

Macintosh accelerator boards (third-party upgrades) that are compatible with HyperCard will have no problems running TEJAS.

More --->

TEJAS V1.0 | 3/30/90 | Help Menu | Define USER...

What You Need to Run TEJAS: Hardware cont'd

TEJAS Version 1.0 has been tested on five Macintoshes:

a. Macintosh SE 030 (68030 processor, 4 Mbytes RAM): beta test site; faster than any other Mac tested. No noticeable delays in any operation.

b. Macintosh II (68020 processor, 4 Mbytes RAM): primary development; exhibited minor delays in some pop-up menus.

c. Macintosh SE (68000 processor, 2 Mbytes RAM): alpha test site; slower than the Mac II because of the Mac II 68020 processor's greater speed.

d. Macintosh Plus (68000 processor, 1 Mbytes RAM): beta test site; runs TEJAS without bombing, but MUCH slower than either the Mac SE or Mac II.

e. Macintosh Portable (68000 static processor, 2 Mbytes static RAM): beta test site; runs TEJAS at approximately the same speed as the Macintosh II.

What You Need to Run TEJAS: Software

TEJAS Version 1.0 was created using HyperCard Version 1.2.1 (5/88) and 1.2.2 (11/88). Either HyperCard version (and all later versions) will run TEJAS Version 1.0 without problems.

HyperCard Version 1.1 will NOT run TEJAS (nor most stacks developed with later HyperCard versions) because many commands and resources required for TEJAS and common to later HyperCard versions are not supported in HyperCard Version 1.1.

HyperCard has been bundled (offered together free) with EVERY Macintosh system sold since August 1987. Apple supports HyperCard and issues upgrades, and it is not write-protected. Therefore, every new Macintosh system owner automatically has HyperCard (although it is the owner's responsibility to install it), and every stack written with HyperCard will run on any of these machines.

How to Install TEJAS

TEJAS Version 1.0 installation has been somewhat automated but still must begin with three simple manual steps:

STEP 1: Make sure that HyperCard is installed on your hard disk. Review "Installing HyperCard on a hard disk" in the "HyperCard User's Guide" that came with your Macintosh. You might wish to put HyperCard and all the folders of other Apple stacks in a folder called 'Hyperfold'.

STEP 2: In the folder where the HyperCard application resides ('Hyperfold' if you followed the suggestion above), create a new folder called 'TEJAS Stacks', and copy all the TEJAS stacks into it.

STEP 3: Open the new 'TEJAS Stacks' folder. Double-click on the stack 'Open Me First!!' to open it, then follow the instructions on the TEJAS Setup Card that appears.

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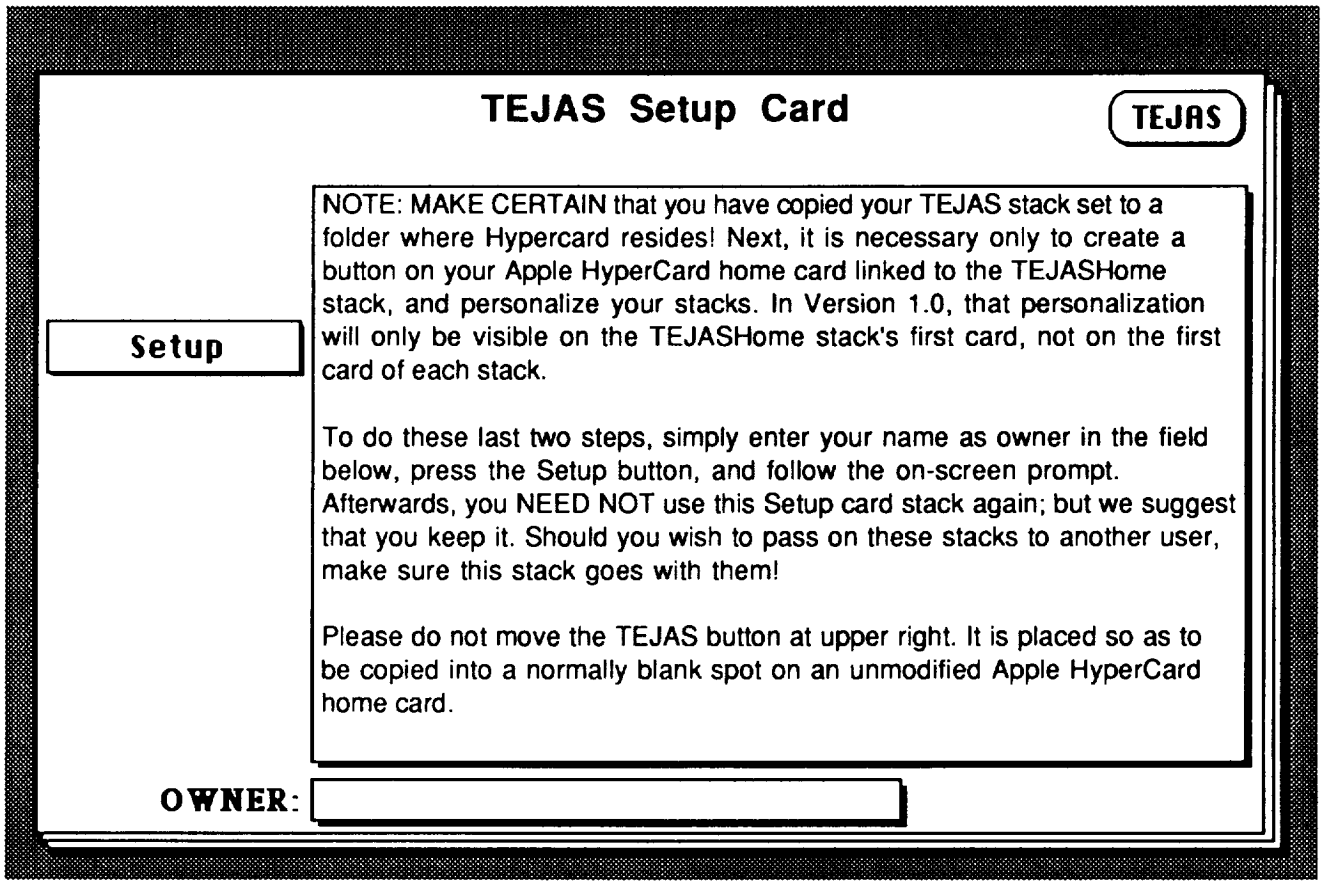


How to Use TEJAS Help

TEJAS Help is an extensive stack that will guide you in using the TEJAS stack system. There are background cards, common user instructions, and a specific section for every TEJAS stack ('stack-specific' help). The cards explain what is there, how to use it, how to change it, and what not to do.

Enter TEJAS Help directly from the desktop, from the TEJASHome card via the TEJAS Help button (Help section 7.1.8), or from ANY TEJAS stack via the pop-up menu attached to the TEJAS boot button (Help section 6.2).

Once at a Help menu, follow the directions in the outlined box to navigate directly to the section you want. Read ALL the cards in a section.

If you entered the Help stack from any other TEJAS stack, you can immediately return to your point of origin (the card you left in pursuit of Help) by clicking on the T-flag button on any Help card (see Help section 6.2). This will work regardless of how much you navigated within Help.

How to Use TEJAS Help

TEJAS Help is so extensive that several aids are provided to speed navigation within the stack.

The Help section is shown in the upper right corner of each Help card, between the Next and previous arrows. Below that number is the Card sequence, showing where you are within a section's cards.

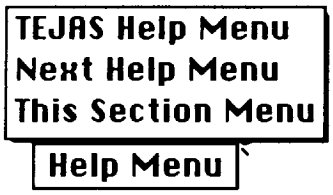
Menu cards are built-in to speed navigating in Help. There are instructions on each menu for its use. Printed, they act as tables of contents.

To make it easy to get to the Help menus, there are two buttons unique to the TEJAS Help stack: Help Menu and ◉ Skip this Menu. Read the next card to understand how to use them to your advantage.

More --->

How to Use TEJAS Help cont'd

Help Menu – this button, found at the bottom right of every card in the TEJAS Help stack, works as follows: Click and hold down on it. You will see a pop-up menu with three items (shown). Drag the mouse up and select an item.



'TEJAS Help Menu' takes you to the first TEJAS Help Menu – the first card in the TEJAS Help stack.

'Next Help Menu' takes you to the next menu in the Help stack (e.g., if you are in section 7.4.3, this selection will take you to the TelePrimitives Help Menu, section 7.5).

NOTE:
If you do not select any item, you will remain in place.

'This Section Menu' will take you to the menu card for any stack-specific help (e.g., if you are in section 7.4.3, this selection will return you to the EVAPrimitives Help Menu for section 7.4), where you can quickly access more help for that stack.

How to Use TEJAS Help cont'd

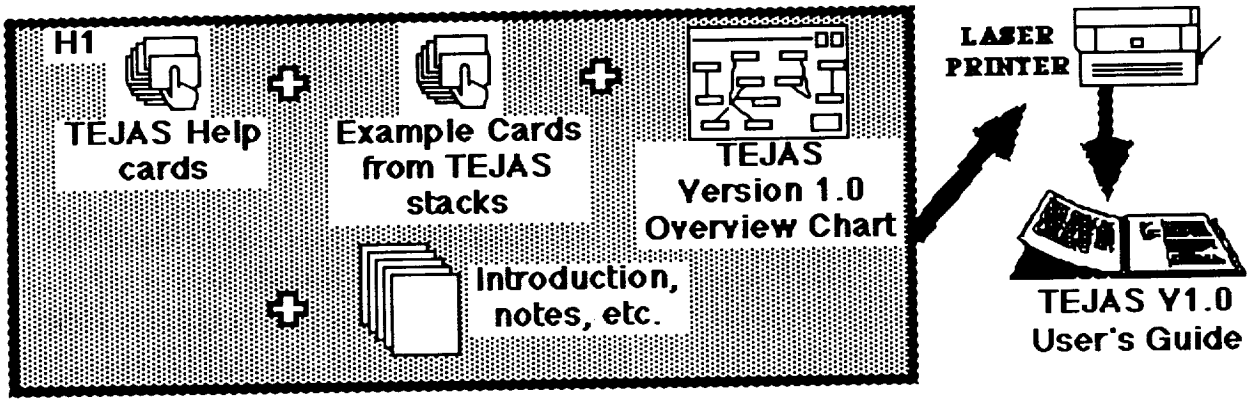
Once you are familiar with TEJAS, you can shorten your search for help by highlighting the ○ Skip this Menu radio button found on the first four TEJAS Help menus. To highlight the button, click on it. It will change to appear dark --> ◉ Skip this Menu (highlight).

If the ◉ Skip this Menu button is highlighted on a TEJAS Help menu card, you will automatically skip that card when you select 'TEJAS Help' from the 'TEJAS boot' button in any stack (see Help section 6.2). Instead, you will go directly to the first Help menu without this button highlighted, skipping menus for general information and common Help, to get right to the menu you want.

The ◉ Skip this Menu button is an extra feature. Use it if you wish.

The TEJAS User's Guide

The TEJAS User's Guide is a printed version of the TEJAS Help stack, with example cards interspersed among the Help cards, and a word-processed Introduction, Index, and Bibliography. The example cards provide reference in the printed Guide; you will not need them in Help when using that stack while TEJAS is up and running on a Macintosh.



TEJAS Version 1.0 Participants

Drews, Michael: tool specification; system and detailed stack design, development and scripting; User's Guide/Help author; project management; TEJAS Editor for Version 1.0

Fiorini, Paolo: TeleTechnologies definitions and forecasting; beta test/review of all stacks; Version 1.0 demo stack development

Hansen, Dr. Bertel: project management (JPL Code ST Projects)

McAffee, Douglas: TeleSystems stack preliminary design

Schenker, Dr. Paul: TeleTechnologies definitions and forecasting

Smith, Jeff H. and group: interactive definition and compilation of Telerobot and EVA task primitives; beta test/review of Primitives stacks

Zimmerman, Wayne: tool specification; system design; project management

Section 4.0

Getting Acquainted with TEJAS Version 1.0

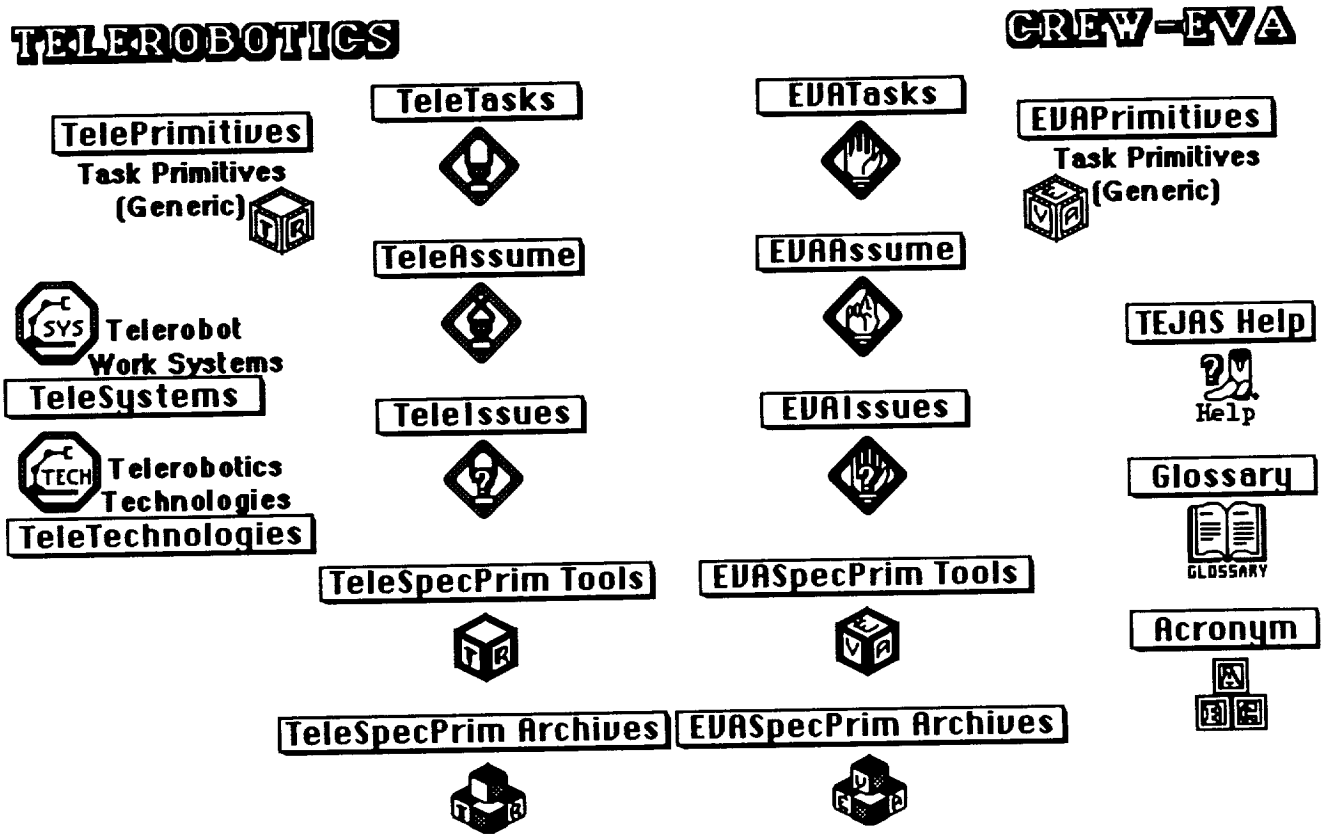
TEJAS Version 1.0 Contents (Stack List)

Please check that your copy of the TEJAS Version 1.0 release contains the following stacks:

TEJASHome	EVATasks	EVASpecPrim Tools
TEJAS Help	EVAAssume	EVASpecPrim Archives
Open Me First!!	EVAIssues	EVATask.5058 Example
Glossary	TeleTasks	TeleSpecPrim Tools
Acronym	TeleAssume	TeleSpecPrim Archives
EVAPrimitives	TeleIssues	TeleTask.4877 Example
TelePrimitives		
TeleTechnologies		

The TEJASHome card and the pop-up stack navigation menus also list the 'TeleSystems' stack, now scheduled for release in mid-1990.

TEJAS V1.0 | 3/30/90 | Help Menu | Define



TEJAS Version 1.0 - What It Does

• Relates EVA and Telerobotics through their specific task primitives. Clearly defines the primitive Verb, details generic Syntax and the primitive's History, and retains the deleted (unincorporated) verbs for future discussion (see Help sections 7.4 and 7.5).

• Interrelates EVA and Telerobot primitives through use of Antonym and Like Verb fields (see Help sections 7.4.11 and 7.5.11).

• Interrelates the Description and Outline, Assumptions, and Open Issues for any EVA or Telerobotic task (Help sections 8.1.7 and 8.4.7), then aids in building a specific task (and any number of derivatives to it) with each of the above (Help sections 8.1.12 and 8.4.12), plus a specific primitives list to approximate the Outline (Help sections 7.4.9 and 7.5.9).

• Provides detailed definition and forecasting on an eight-level readiness system for all telerobotics technologies listed (see Help section 7.7.9).

TEJAS Version 1.0 - What It Does cont'd

TEJAS demonstrates that linked hypermedia stacks can serve as a

• User/researcher-compiled standard reference

• Standard analysis tool

• Communications medium between disciplines, projects, and centers that is compatible with their common in-house equipment

• Thought tool – a way to link, compare, and contrast data across project or technology boundaries, so that any user can follow WHO the originator was, HOW they were thinking, and WHY they reached a particular conclusion.

TEJAS Version 1.0 Reference Stacks Overview

EVA and Telerobot Primitives (EVAPrimitives, TelePrimitives)
- Contains first-ever compilation of verb-oriented task primitives from major crew-EVA and telerobotics Task Analysis Methodologies (TAMs) nationwide
- Includes Verb, Definition, generic Syntax, Like Verbs (related terms, NOT synonyms), Antonym, and History fields
- Helps standardize TAM primitives, relate methodologies, and eliminate redundancies. Contains more telerobot primitives than EVA, more exact.

(see Help sections 7.4 and 7.5)

Telerobotics Technologies (TeleTechnologies)
- Contains one card per space telerobotics technology, for ALL technologies (not just some arbitrary list of 'critical' technologies)
- Includes Definitions and Forecasts (with histograms), via an 8-level technology readiness system
- Includes NASREM (NASA/NBS Standard Reference Model) classification for each technology (see Help section 7.7)

TEJAS Version 1.0 Reference Stacks Overview

Telerobotics and EVA Glossary of Terms (Glossary)
- Contains over 1100 commonly used (and misused) terms, one per card
- Includes up to three definitions (each with a source)

(see Help section 7.2)

Acronyms and Abbreviations Dictionary (Acronym)
- Contains over 800 commonly used (and misused) acronyms and abbreviations, one per card
- Includes up to five definitions (each with a source) from NASA and industry documents

(see Help section 7.3)

TEJAS Version 1.0 Analysis Stacks Overview

Task Summaries (EVATasks, TeleTasks)
- Contains card summaries (one per task) of any EVA or Telerobotics task
- Includes Task Name, Description, Outline fields

(see Help sections 8.1 and 8.4)

Assumptions (EVAAssume, TeleAssume)
- Contains cards for listing assumptions about workplace, task flow, tools, ORU's, etc.; one assumptions card per task
- Aids in technology requirements analysis

(see Help sections 8.2 and 8.5)

Open Issues (EVAIssues, TeleIssues)
- Contains cards for listing what is NOT resolved about a task you are analyzing; one open issues card per task

(see Help section 8.3 and 8.6)

TEJAS Version 1.0 Analysis Stacks Overview

Specific Primitives Tools (EVASpecPrim Tools, TeleSpecPrim Tools)
- Contains three cards only (SpecPrims List, SpecPrim Builder, SpecPrim Args Menu) that work interactively with other cards in a specific task stack
- Aids in building specific primitives in a Specific Task stack (see below)

(see Help sections 9.1 and 9.4)

Example Specific Task Stacks (EVATask.5058, TeleTask.4877)
- Created from Task Summaries; each stack contains Task Summary, Assumptions, and Open Issues cards for one task, three cards that build specific primitives (above), and a card that provides primitive verb menus
- Used to specify the specific primitives for any task
- Allows creation of derivatives of any specific task at any point in the analysis (see 'Building a Specific Task,' Help sections 8.1.12 and 8.4.12)

NOTE: EVATask.5058 and TeleTask.4877 are EXAMPLE STACKS only. You can create an unlimited number of these stacks using TEJAS (see Help sections 9.3 and 9.6).

TEJAS Version 1.0 Analysis Stacks Overview

Specific Primitives Archives
(EVASpecPrim Archives, TeleSpecPrim Archives)
- Contains separate cards for each primitive verb, arranged alphabetically by verb (similar to EVAPrimitives and TelePrimitives stacks, but excluding the deleted verbs), with a single scrolling field that archives all specific primitives using that verb. To appear here, these specific primitives must first be built by the user within a specific task stack (on the SpecPrim Builder card, see Help sections 9.1.8 and 9.4.8), then archived with the Archive List button (on the SpecPrims List card, see Help sections 9.1.7 and 9.4.7).
- Aids in reusing specific primitives already built within a specific task stack (see Help sections 9.2 and 9.5). Provided as a convenience for internal use (e.g., group, section, division etc.), NOT as an attempt at standardization of SPECIFIC primitives for the entire community.

(see Help sections 9.2 and 9.5)

Transporting TEJAS Data

TEJAS is NOT meant to replace, but to augment existing microcomputer software tools. Although TEJAS data is stored in HyperCard stacks, this data can, if desired, be exported to or imported from another program in many ways (see Help sections 5.1 to 5.6). Therefore, your analysis needn't hinge on HyperCard, nor on a particular stack's design. By transporting TEJAS data into your existing applications, you can take full advantage of your specialized macros and formulae.

In a future application, HyperCard could act as a user-customizable front-end for any database, spreadsheet, or word-processed file (where you see only a HyperCard card). For example, complicated HyperTalk scripts could call on a number-crunching application to calculate and graph data, solve equations, create and store files, print, etc. The TEJAS Version 1.0 scripts don't do this, however. If they did, using TEJAS would then require owning, installing, and configuring those other applications, lessening the total Macintosh compatibility HyperCard automatically gives you.

Communicating with Hypermedia

The data in the TEJAS Version 1.0 stacks is useful for a variety of applications but is best transported as stackware. Here's why:

Stackware is software, but it is hypermedia (reactive media) too. Stacks can do more than list text and numbers, or show static two-dimensional graphics (like the histograms in the TeleTechnologies stack). With hypermedia comes audio, video, and file manipulation capability.

Therefore, the TEJAS stacks are intended as a communications medium, too. When you check a stack that someone sends you against your copy of it, you can see RELATIONSHIPS between terms, systems, primitives, technologies, etc. – something not possible on paper. Using the Find... command, you can quickly read what you need and ignore the rest.

In short, the stacks are best left as stacks. SAVE TIME: don't print stacks, exchange stackware! You will quickly find other uses for hypermedia.

Modifying Existing Cards

You can modify cards by adding and deleting text fields and buttons, changing the background and card pictures, or entering or deleting text in existing fields (see the "HyperCard User's Guide" for details).

WARNING: If you wish to add NEW background fields and buttons, you can. But you therefore assume responsibility for explaining each button or field's use, filling in new fields on EVERY card in the stack, justifying each change, and so on. This is a considerable job – don't leave it half done.

Please avoid adding card fields or buttons, or changing the card picture. These changes are time-consuming and expensive to reconcile.

The TEJAS Help stack cards are protected by a HyperTalk script to prevent you from deleting them. Please do not change the Help cards in ANY way. If you do and you transfer these stacks, the next user will not get the original Version 1.0 stack. Suggest changes in the User Notes field instead.

Adding Cards

New cards may be added to any stack at any time. These may include primitive verbs, terms and acronyms, technologies, etc. The TEJAS Editor welcomes and encourages such additions, especially to the reference stacks. Each added card will be identified, read, and compiled in any updates or later TEJAS versions.

Each TEJAS stack has specific Help cards (see Help sections 7.1 to 9.6). Before adding cards, please refer to the 'Adding Cards' Help card for the stack you're in and read the rules for that stack.

Deleting Cards

NEVER DELETE ANY CARDS FROM ANY REFERENCE STACK, OR FROM THE TEJASHome OR TEJAS Help STACKS!!

Deleting cards is, in general, a very poor idea. Without exception in TEJAS, all cards serve a purpose. Sometimes they control the way a stack works. Most often, they provide information.

ONLY in the TEJAS analysis stacks should cards EVER be deleted. When released, these stacks contain only example data; they exist to store whatever you enter. You can delete your data if you want. But even in the analysis stacks, there are cards you should NEVER delete.

Each TEJAS stack has specific Help cards (see Help sections 7.1 to 9.6). Before deleting cards, please refer to the 'Deleting Cards' Help card for the stack you are in, and read the rules for that stack.

TEJAS Updates and Later Versions

Compiling suggested changes, additional information, and comments must be directed by an impartial group. Until that group is identified, the TEJAS Editor will continue maintaining, updating, and augmenting the stack system (through FY 1990).

Additional TEJAS stacks (such as the TeleSystems stack due out in early 1990) will bear release numbers of 1.1 to 1.9. When enough comments and changes have been received, tested, debated, and compiled, a new version of the entire TEJAS stack system (2.0) may be released.

For each release, an interactive installation routine (much more complex than the one for Version 1.0) will give you a choice: update the existing stacks or replace them with new versions. Updating will carefully modify the reference stacks, preserving items you specify (such as User Notes, additional definitions, etc.), but changing the standardized reference information (clearly identified) so that no information is lost.

The User's Role

Hypermedia communications works best if the flow of ideas is TWO-WAY. The TEJAS Editor needs your inputs to help the entire commmunity.

USE the stacks. Modify the information if it is wrong, and send the modified stacks back. Add your other comments in the User Notes field. We will use scripts to identify and flag all changes, then compile them for the next version. This can continue as long as it helps the community.

Detailed instructions are on 'The User's Role' cards in the stack-specific Help (sections 7.1 to 9.6).

Section 5.0

Input and Output

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Input: Importing From Text Files

Reference documents – such as acronym lists and glossaries (of terms) – are often compiled as text files. Considerable information may be (and has been) transferred from them into the TEJAS reference stacks. There are three basic methods of importing text into TEJAS information fields:

1. Manually cut and paste specific items from spreadsheet to stack cards. With enough RAM, MultiFinder will run both HyperCard and a text application simultaneously (see Help section 3.3 about RAM limits).

2. Type the text onto cards. This can be the fastest way, if the amount of data is not too great and you have insufficient RAM to try method 1.

3. Build a macro or HyperTalk script to automate the process. For this, you need detailed knowledge of both the originating file and the HyperCard stack. The TEJAS Help cards give details on all TEJAS information fields; it is up to you to write the code (or request it from the TEJAS Editor).

Input: Importing From Spreadsheets and Database

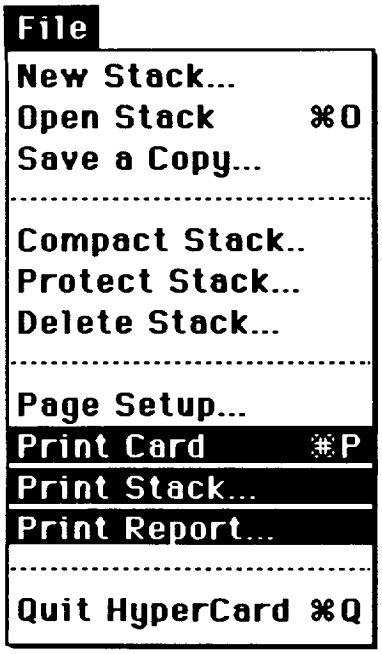
HyperCard's main utility is as an information manager that collects, sorts, stores, and finds data. It is not a spreadsheet program, nor a number-cruncher. But people often use spreadsheets and databases. If input from these is desired for one of the TEJAS stacks, it can happen in three ways:

1. Manually cut and paste specific items from spreadsheet to stack cards. With enough RAM, MultiFinder will run both HyperCard and a text application simultaneously (see Help section 3.3 about RAM limits).

2. Type the information onto cards. This can be the fastest way, if the data amount is not too great, and you have insufficient RAM to try method 1.

3. Build a macro or HyperTalk script to automate the process. For this, you need detailed knowledge of both the originating file and the HyperCard stack. The TEJAS Help cards give details on all TEJAS information fields; it is up to you to write the code (or request it from the TEJAS Editor).

Output: Printing TEJAS Stacks and Cards



The following commands let you print an exact record of what you see on the screen:

To print TEJAS cards individually, one to a page, use the 'Print Card' command.

To print the entire stack of cards, use the 'Print Stack...' command.

Use the 'Print Report...' command for text not visible on scrolled fields (Help section 5.4).

See the "HyperCard User's Guide" for a full explanation of these commands.

More --->

Output: Printing TEJAS Stacks and Cards

A few tips about printing in HyperCard:

HyperCard printing is quite slow; this will doubtless be improved with the next release of the application. The more RAM you have in both computer and printer, the faster it will print. Printing 'text-only' reports is much faster, but for card or background pictures (such as the histograms in the TeleTechnologies stack), you MUST print either the card or the entire stack if you need hard copy.

Caution: extensive TEJAS data is best used in stack form. AVOID PRINTING ANYTHING – cards, stacks, or reports – when possible. TEJAS Verson 1.0 is very large. Remember that even text reports may be up to 200 pages!

Output: Printing TEJAS Reports

The 'Print Report...' command from the 'Edit' menu allows you to print text-only reports from the background and card fields of any TEJAS stack. You may choose any combination of fields to print, in several styles, by using the dialog box that appears when you select 'Print Report...'

HyperCard versions 1.2.1, 1.2.2, and 1.2.5 do not provide a way to print a text-only report from particular cards. You must print the entire stack. See the "HyperCard User's Guide" for a full details.

For some printouts, the TEJAS project used the "Reports" program by Activision, Inc. This program allows greater flexibility with reporting style for HyperCard stacks and is somewhat faster.

Caution: extensive TEJAS data is best used in stack form. AVOID PRINTING ANYTHING – cards, stacks, or reports – when possible. TEJAS Verson 1.0 is very large. Remember that even text reports may be up to 200 pages!

Output: Exporting to Text Files

Because of HyperCard's limited text processing and printing capability, it is sometimes best to export text fields to word-processing programs. There are various commercial DA's (Desk Accessories), stand-alone programs, and even some HyperCard stacks that export text fields. But TEJAS deliberately avoids providing a quick-and-easy way to save an entire stack as text, because such a handy utility would quickly lead to two problems:

- breakdown in configuration control
- duplication of known data as printed media

It is simple to create a short HyperTalk script that will transfer all text from a stack into a document. A number of books are available that explain how. Several of them are listed as references in the TEJASHome stack.

Remember, you can always use the mouse to cut and paste discrete text from any TEJAS stack to any word-processed document.

Output: Exporting to Databases and Spreadsheets

TEJAS Version 1.0 analysis is limited. But different Task Analysis Methodology (TAM) efforts nationwide have created extensive, useful databases and spreadsheets, with built-in formulae and macros. These TAMs generally deal with specific task primitives. You can create these specific primitives in TEJAS, then export them to a spreadsheet for analysis.

In TEJAS, specific primitives are found only in specific task stacks (e.g., EVATask.5139, TeleTask 4722, etc.) that are created from the EVATasks and TeleTasks stacks (see Help sections 8.1.12 and 8.4.12). Built into the SpecPrims List card (Help sections 9.1.7 and 9.4.7) in every specific task stack is the only automated data exporting function in TEJAS Version 1.0. This routine dumps the list of specific primitives to the text-only files "Transfer spreadsheet" and/or "Transfer document".

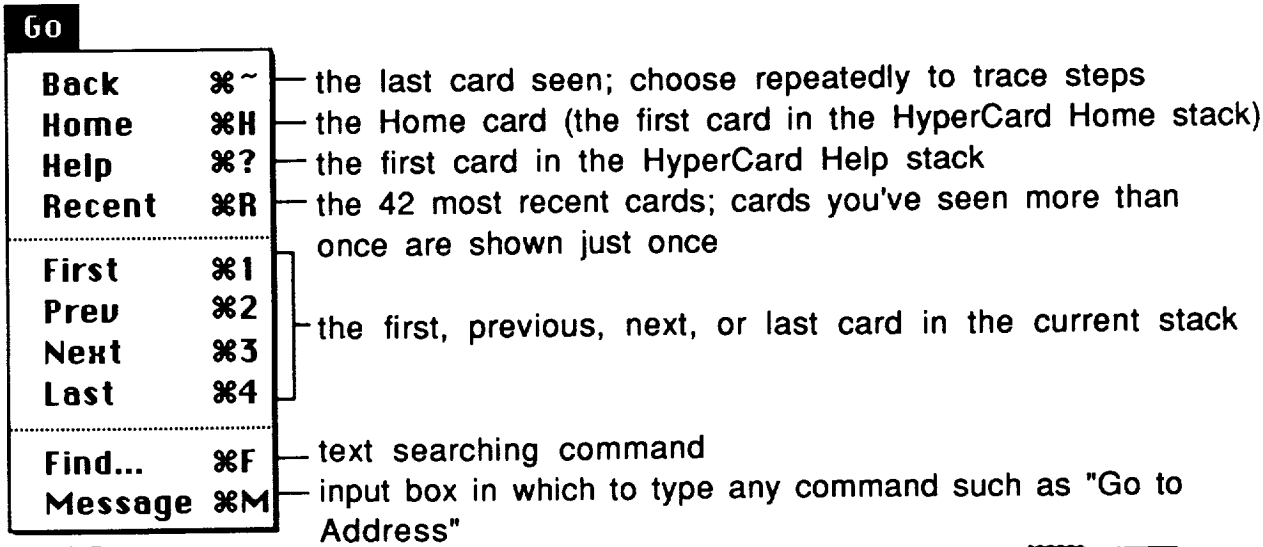
For a full explanation of TEJAS task analysis capabilities, see Help sections 8.1.6, 8.4.6, and 9.1 to 9.6.

Section 6.0

User Instructions - Common Help

TEJAS Common Navigation and Action Commands

Please see the "HyperCard User's Guide" (c) Apple Computer, Inc., Cupertino, CA, 1988, or the built-in HyperCard Help stack for a complete explanation of the following commands from the 'Go' menu:



TEJAS Common Navigation and Action Commands

A few important words about the 'Find...' command:

To find a word, phrase, or number (any character string) in any stack, select 'Find...' from the 'Go' menu (or type ⌘F). The message box will appear (if it's not already visible) with the Find command in it. Type the character string inside the quotation marks. Hit the Return key to activate the search, and the card containing the first occurrence of that string will appear, with the string outlined (e.g., [string]).

If that occurrence of the string is not what you wanted, hit the Return key again (before you do anything else). Keep hitting the Return key until you find the string you want. Find will check ALL fields, locked or unlocked. Use the Return-Find sparingly at first; it can be confusing, and for searching out common strings (such as 'telerobot'), quite wearisome.

For a better way to search text within TEJAS, see the next card -->

TEJAS Common Navigation and Action Commands 6.1 3 of 4

A tip about searching in TEJAS:

Wherever practical, TEJAS provides a HyperTalk script (software code) to shorten the search for a particular word or phrase. Usually these script utilities search only the fields that identify the card's subject such as a primitive verb or technology name.

These HyperTalk scripts are attached to buttons and locked text fields, and may use a pop-up menu (all explained further in the following cards). There may be several utilities in the same stack, deliberately inserted to give you greater flexibility and speed in text searches. You will usually save a lot of time if you use them instead of executing the 'Find...' command.

Be certain to check the Help cards for the stack in which you're searching for these built-in TEJAS utilities. If a particular search routine would be useful but isn't incorporated, please let the TEJAS Editor know.

TEJAS Common Navigation and Action Commands 6.1 4 of 4

A few words about the 'Compact Stack' command (in the File menu):

This is a vitally important comand to know (and use wisely) in order to keep your stacks manageable, both in operating speed and storage.

HyperCard stacks are much larger than commonly encountered files. The application reserves disk space in 8 kilobyte increments for a growing stack. Initially, all that space is used. But free space is introduced into a stack each time you delete a card, background, field, or button; the more free space in a stack, the slower and larger the stacks. You can monitor the free space by selecting 'Stack Info...' from the Objects menu.

The 'Compact Stack' command rearranges the current stack on your hard disk, deleting any free space. The larger the stack and the more free space, the longer this command takes to execute. But it's worth the wait. You should use 'Compact Stack' at the end of each session with a TEJAS stack.

TEJAS Common Navigation and Action Buttons

HyperCard allows you to create an unlimited set of programmable on-screen buttons. TEJAS takes full advantage of buttons, either to navigate within and between the various stacks or to provoke an action such as hiding or showing fields or pictures.

Buttons work because subroutines of HyperTalk code, called scripts, are attached to them (see 'Button Info...' in the "HyperCard User's Guide"). In TEJAS, these scripts are optimized to operate within the stack system. They can offer many different ways to find or use a particular piece of information, thereby building flexibility into the interface with you. Don't be afraid to try them.

If anything about a button seems contrary, too subtle, or not intuitive – the icon, the speed, the action – please make a note in the User Notes field (see Help section 6.5).

TEJAS Common Navigation and Action Buttons

TEJAS buttons are of most of the seven standard HyperCard types – transparent, opaque, rectangle, shadow, round rect, check box, and radio button (see the "HyperCard User's Guide").

Icon buttons have been used wherever possible in TEJAS, to save screen space, build an intuitive interface, and give uniformity within and between stacks. Over two dozen icon buttons were created especially for TEJAS. Some examples:

These are explained in the TEJAS Help cards for each stack.

NOTE: Any button with a 'pop' symbol (⁂) on it supports a pop-up menu! TEJAS has quite a few of these menus, again to save space. Look for the ⁂!

The next cards explain buttons that are common to ALL TEJAS stacks.

TEJAS Common Navigation and Action Buttons

Home - always takes you back to the HyperCard Home card, however your Home card is configured. This same icon is found at the bottom left corner on every card in every TEJAS stack.

Next - advances you through the cards in any stack. Found at the bottom center of every card in every TEJAS stack (except TEJAS Help).

Previous - takes you back one card at a time within a stack. Found at the bottom center of every card in every TEJAS stack (except TEJAS Help).

T-flag - will return you from a pursuing a definition or some help from the TEJAS Help stack to the card you left, even if you have moved within the Glossary, Acronym, or TEJAS Help stacks, or used the Define button again. Think of T-flag as a 'bookmark' that keeps your place. Use it to save time finding your point of origin. Found at the upper right corner of every card in every TEJAS stack (except TEJAS Help - see it?).

TEJAS Common Navigation and Action Buttons

Show - this button quickly displays all the cards in any stack, so fast that you'll barely be able to scan them. When you see the card you want, or wish to stop the search, just click the mouse (anywhere). The display will stop, probably a few cards past the card you want. Click on the Previous button (left arrow) until you get back to the card you want.

Sort - this button works differently in different stacks. Usually Sort functions alphabetically in the fields that list the card subject, such as the primitives Verb field. See the TEJAS Help cards for a particular stack. In some stacks, a warning will appear with an option to cancel the command.

BEWARE! If you use Show or Sort in any large stack (such as the Glossary and Acronym stacks, each approximately a thousand cards), you may be in for a long wait. These commands are RAM-intensive, and completion times vary by stack size, RAM cache size, and your processor. Do not use either button trivially in large stacks, and read the Help cards for each stack.

TEJAS Common Navigation and Action Buttons

EVAPrimitives
TelePrimitives
TeleSystems
TeleTechnologies

EVATasks
EVAAssume
EVAIssues

TeleTasks
TeleAssume
TeleIssues

Glossary of Terms
Acronyms & Abbrev.

TEJAS Help
This Stack Help

TEJAS boot - found at the bottom left (next to the HOME button) on every card in every TEJAS stack; speeds navigating between stacks.

Click and hold down the mouse button on the boot to reveal a pop-up menu (at left), which works like any other Macintosh menu. Select a TEJAS stack from the menu by holding down the mouse button, dragging the cursor until a stack name illuminates, then releasing. The script takes you immediately to the first card of that stack.

IMPORTANT: If you fail to select an item (i.e., drag the cursor off the menu and release the mouse button, or click once quickly on this button), you will go directly to the TEJASHome card. More -->

TEJAS Common Navigation and Action Buttons

EVAPrimitives
TelePrimitives
TeleSystems
TeleTechnologies

EVATasks
EVAAssume
EVAIssues

TeleTasks
TeleAssume
TeleIssues

Glossary of Terms
Acronyms & Abbrev.

TEJAS Help
This Stack Help

TEJAS boot (cont'd) - the last two menu items are important. Use them to get Help, then return to your point of origin by clicking on the .

'TEJAS Help' takes you back to the first TEJAS Help Menu at the beginning of this Help stack.

'This Stack Help' takes you to the Help menu for whatever stack you are in, bypassing the TEJAS Help stack's introductory and Common Help cards. It's a more direct route to Stack-Specific Help.

The TEJAS boot button is one of the fastest ways around the stack system, saving you time by bypassing the TEJASHome card, finding Help, or getting you back to TEJASHome. Lost? Click on it!

Define - found at the bottom right on almost all cards in TEJAS, this button lets you access cards in the Glossary of Terms and Acronyms and Abbreviations Dictionary at any time during your work in TEJAS.

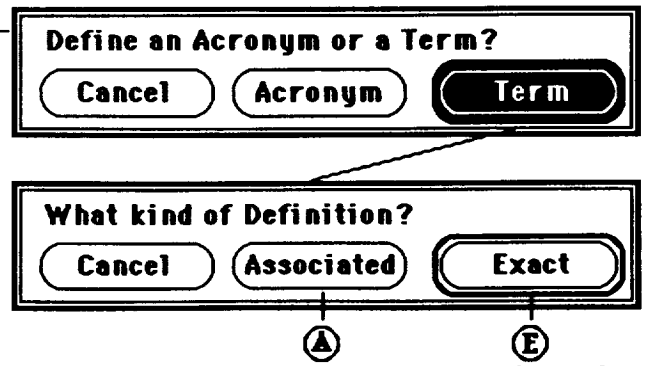
This utility is provided because EVA and Telerobotics are extremely complex areas of research, requiring constant reference. With a plethora of terms and multiple definitions, a suitable 'dictionary' that covered both areas simultaneously did not exist. The Glossary and Acronym stacks were created to fill this need (see Help sections 7.2 and 7.3), and the Define button was created to use them as hypermedia.

When you use Define in any stack except Glossary, Acronym, or TEJAS Help (this stack), the button 'saves your place.' If you want to search for other terms or acronyms in those two stacks, just use Define again, or the Next, Previous, or Show buttons. After you have the information you need, click on , and you will return to where you started the search.

Define - Define works via a complicated HyperTalk script to help you search and navigate through the Glossary and Acronym stacks. It is useful to know exactly how the Define search works.

Define

When the Define button is clicked, it highlights, and shows the first dialog box.



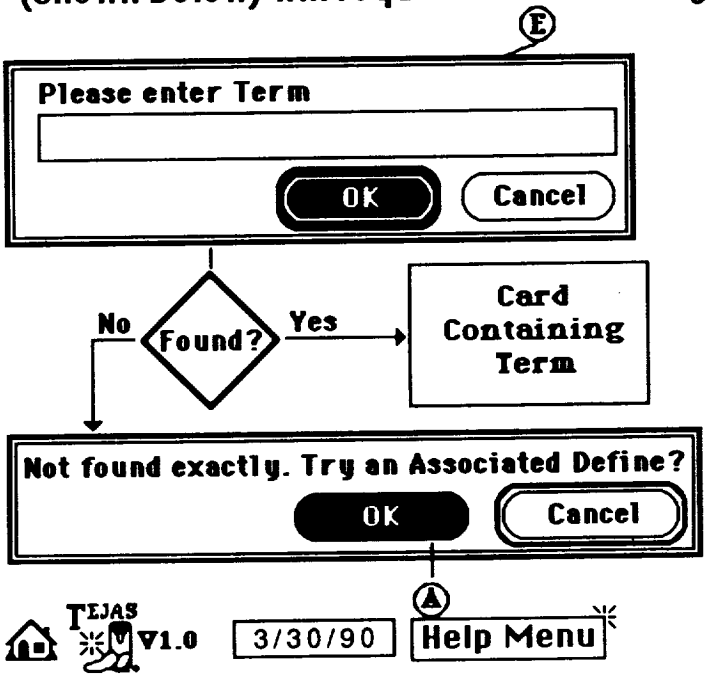
NOTE: You can Cancel the search at any time

If 'Term' is selected, TEJAS next wants to know if you wish an Associated or Exact term defined. If you know exactly what you're looking for (e.g., 'gripper'), choose Exact. If you're not certain how your term may be listed (e.g., 'shared control' or 'control mode: shared' etc.), choose 'Associated.'

More -->

TEJAS Common Navigation and Action Buttons

Define - If you selected an Exact term definition, the input dialog box (shown below) will request the term and give you another chance to Cancel.



If you click 'OK,' the script will start the search. If it finds an EXACT MATCH for your term, you will go to that card in the Glossary.

If Define does not find an EXACT MATCH for what you typed, it is still possible that your word or phrase is in the Glossary, perhaps rearranged a bit or contained within an associated term. The script will ask to try an Associated Define.

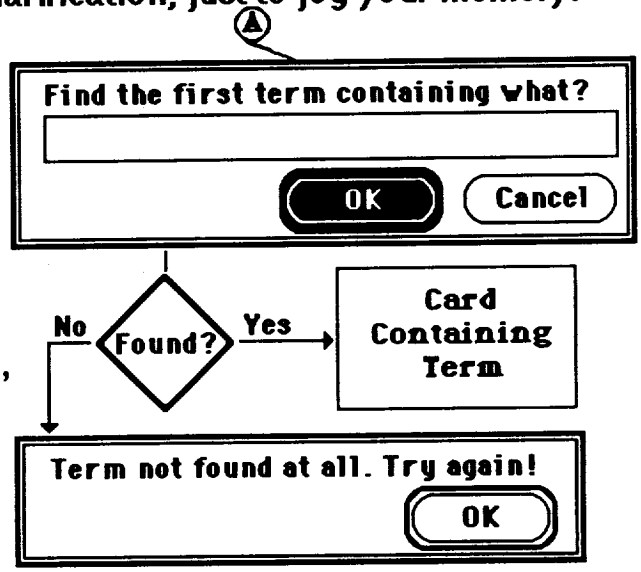
More -->

TEJAS Common Navigation and Action Buttons

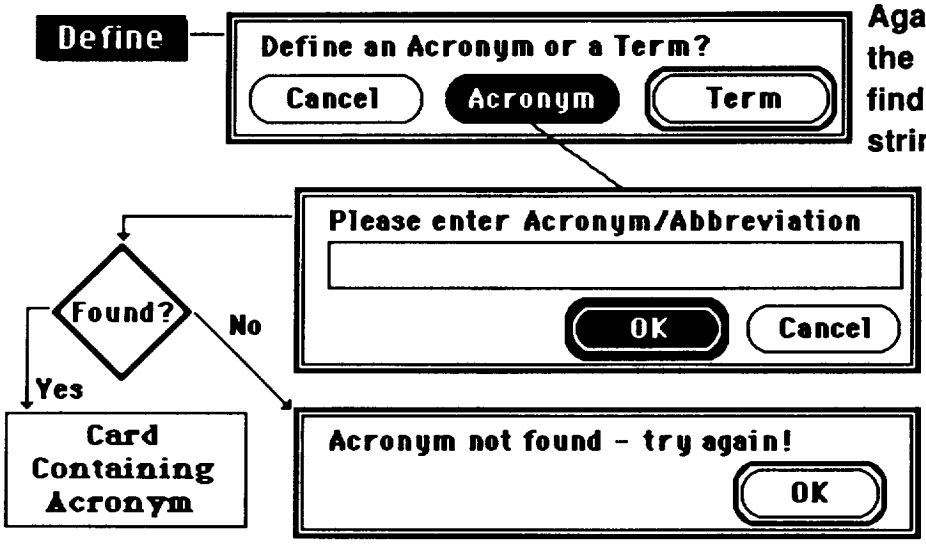
Define - If you selected an Associated term definition, the input dialog box will request the term with a little clarification, just to jog your memory:

The request means just that: the script will alphabetically search the Glossary, until it finds the first term that CONTAINS your word or phrase.

EXAMPLE: if you select an associated definition of "telerobot," Define will yield (in TEJAS Version 1.0) "Primitive, Telerobot (Generic)"; this is certainly an associated term, but hardly what you wanted. You will have to Define again. That's why you should always start term searches with Define Exact.



Define - Defining acronyms and abbreviations is somewhat simpler. The sequence is as shown: select 'Acronym' in the first dialog box; this leads to another input box. Enter the character string you want and click 'OK.'



Again, you can cancel the search. If the script finds a match for your string, it will take you to that card in the Acronym stack. If not, you will get the message below.

Compound acronyms (e.g., JEM-RMS) can lengthen the search. Be persistent.

Some tips for using Define with TERMS:

• With Exact Defines, single words will be found much faster than phrases or multiword terms.

• For multiword terms (such as "shared control"), enter them as such, NOT as a hierarchical list separated by commas (e.g., "control, shared").

• If a search fails, try breaking down the term into key words and finding all the associated terms. For example, an Exact Define of "degree-of-freedom" finds no match. An Associated Define yields "Limited-degree-of-freedom Robot." But the key words are "degree" and "freedom"; either of these finds "Degrees of Freedom." This example also illustrates how to overcome hyphenation in a term, whether expected or not – do a key word search.

See Help section 7.2 on the Glossary stack for more insights.

TEJAS Common Navigation and Action Buttons

Some tips for using Define with ACRONYMS and ABBREVIATIONS:

- **Searching for acronyms and abbreviations is much faster than searching for terms because nearly all entries are single word terms.**

- **Hyphenation can still cause multiple 'successful' searches that don't give you the acronym or abbreviation you want. Just repeat the Define. There are not many hyphenated acronyms in the stack.**

- **See Help section 7.3 on the Acronym stack for more insights.**

TEJAS Common Navigation and Action Buttons

USER.. **User Notes - found at the lower right on almost all TEJAS cards in the reference stacks (including Help), this button gives you access to a scrolling text field called 'User Notes,' where you can type in whatever comments you may have. If something is missing or you disagree with a definition, a forecast, a numerical value, an icon, the way something works or is explained – ANYTHING – note it on this 'scratch pad.' Then you can either print this field for all the cards in a stack, or return a copy of the stack to the TEJAS Editor, who will review and respond to these suggestions.**

Information vs. Comment vs. Configuration Fields

There are three types of TEJAS fields:

INFORMATION fields are used for data input on each information card. Specific instructions for each field are found in the 'Information Fields' Help cards for each TEJAS stack.

COMMENT fields, found on every card of any stack, are provided as a personal notepad. In this field you can communicate your ideas, critiques, even justifications for changes to another user, or between any user and the TEJAS Editor. TEJAS Version 1.0 contains only one comment field, described in the 'TEJAS Common User Notes Field' card (Help section 6.5).

CONFIGURATION fields, found on every card of any stack, are locked. Their function is described in the 'Configuration Fields' card (Help section 6.4).

TEJAS Common Configuration Fields

Date: locked, unlabeled rectangle field at bottom left (see arrow (1)). Shows date the card was last modified; changes automatically to current date with a change in any field's contents. Used for configuration control for the TEJAS user and Editor; can be used to search for latest changes in an evolving stack.

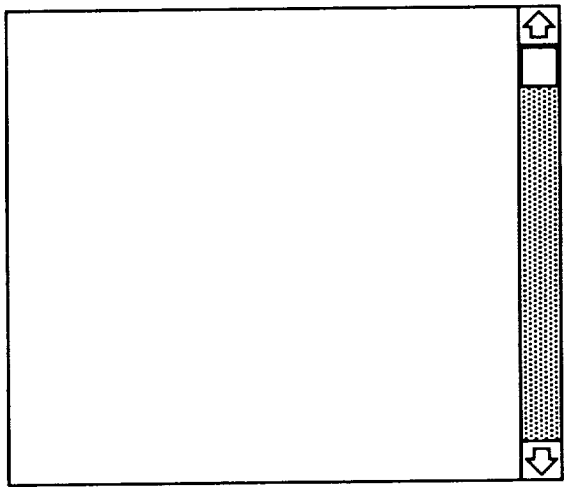
TEJAS Version: locked, unlabeled transparent field to the right of the TEJAS boot at lower left (see arrow (2)). Contains "VX.X" (original version number, e.g., V1.1); changes automatically to "VX.X+" with a change in any information field's contents (but NOT with changes or additions to the User Notes field). Used for configuration control, for the user and originators.

NOTE: any "VX.X+" cards have been modified before you received them; they are NOT an original release!

TEJAS Common User Notes Field

User Notes: unlocked, unlabeled, hidden scrolling field appearing at card center when the 'User Notes' button is pressed. Use as a 'notepad,' to transfer thoughts, comments, complaints, or notes.

'User Notes' field shown as it appears on-screen --->



NOTE: When this field appears, the card picture will be hidden. This may change the appearance of the card; It will be restored when the 'User Notes' is pressed again, hiding this field.

TEJAS Information Fields

Information fields are the text fields that store both text and numbers in TEJAS. They are different in purpose from Comment and Configuration fields (see help section 6.3.). There are five possible types of fields: transparent, opaque, rectangle, shadow, and scrolling. In addition, fields can be either hidden (i.e., invisible unless shown by pressing a button or otherwise executing a "show field" command) or visible. Please see the "HyperCard User's Guide" (c) Apple Computer, Inc., Cupertino, CA, 1988, or the built-in HyperCard Help stack for a complete explanation of fields and their properties.

There are no information fields common to all TEJAS Version 1.0 stacks.

Specifications for and use of information fields for each TEJAS stack are described in the 'Information Fields' section of that stack's TEJAS Help cards. See the Help menus for the individual TEJAS stacks to find the appropriate section number.

Section 7.0

User Instructions - Reference Stack

Section 7.1

User Instructions - TEJASHome Stack

PAGE 6-60 INTENTIONALLY BLANK

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TEJASHome Help Menu

Menu 1 of 1

7.1 User Instructions

Background:

- ☐ 7.1.1 General Information
- ☐ 7.1.2 The User's Role
- ☐ 7.1.3 Changing the Standard
- ☐ 7.1.4 Adding Cards
- ☐ 7.1.5 Deleting Cards

Unique!

Stack-Specific Help:

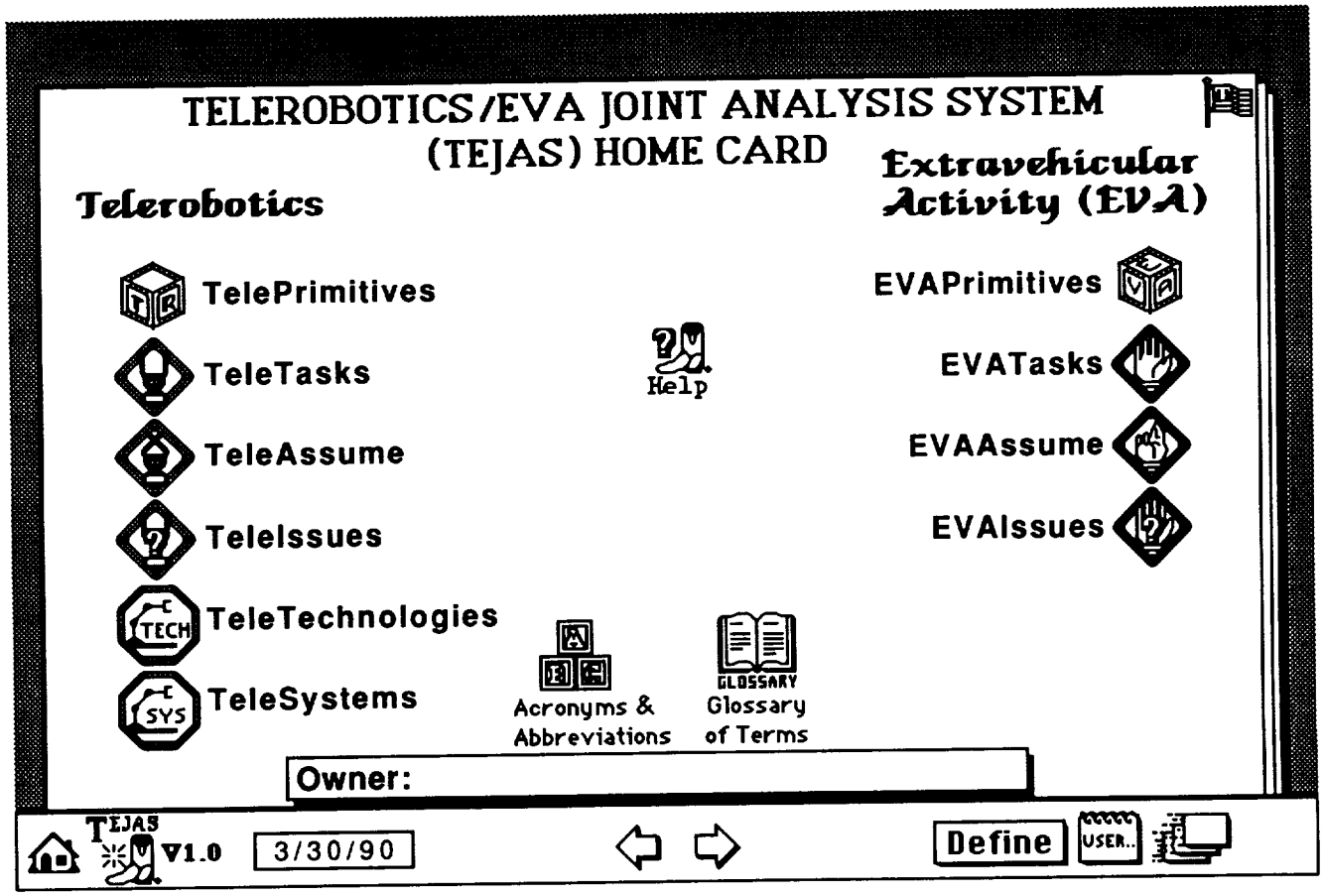
- ☐ 7.1.6 Card Backgrounds
- ☐ 7.1.7 Information Fields
- ☐ 7.1.8 Buttons

Unique!

- ☐ 7.1.9 Stackware
  Bibliography Card

INSTRUCTIONS:
Click ☐ box to access section;
Click arrows to page through Help stack;
Click 'T-flag' to return to point of origin.

TEJAS V1.0 | 3/30/90 | Help Menu | Define | USER..



TEJASHome Stack - General Information

TEJASHome is 'home base' (i.e., the 'root directory') for the TEJAS stack system. Most of the time, you will never need to visit here. But if you ever do get lost in the stacks, clicking once on the 'TEJAS boot' button (see Help section 6.2) in the lower left-hand corner of EVERY card in EVERY stack will take you to TEJASHome. From the TEJASHome card, you can enter any stack in the TEJAS stack system

You SHOULD include this stack with any smaller subset of TEJAS that you use or distribute because there are scripts in each stack that refer to it.

As an example, TEJASHome comes with the TelePrimitives, EVAPrimitives and TEJAS Help stacks released on a single disk with the document, "Generic Extra-Vehicular Activity (EVA) and Telerobot Task Primitives for Analysis, Design, and Integration, Version 1.0: Reference Compilation," JPL Publication 90-10.

TEJASHome Stack - The User's Role

TEJASHome is a reference stack provided to aid navigation within TEJAS. There is nothing to change in this stack, since all text fields are locked. Please DON'T TAMPER with any objects – field, button, picture, script, etc. Don't even move them.

The text field "My Copy" (located at the bottom, with the label "OWNER" in front of it) is automatically filled with the owner's name when installing TEJAS, if you followed the directions on the 'How to Install TEJAS' card (Help section 3.5). Whenever this stack is reinstalled using the 'Open Me First!!' stack, this field may change. That is the ONLY thing that may change in TEJASHome.

TEJASHome Stack - Changing the Standard

This is an important stack for navigation, for introducing the TEJAS symbology, and for documenting software and references used in TEJAS' creation. If you think that changes should be made to either card in this stack, please suggest them in the User Notes field (see Help section 6.5). Otherwise, this stack – especially the first card – is a standard only to TEJAS. No other mechanism is needed for changing the standard.

TEJASHome Stack - Adding Cards

DO NOT ADD ANY CARDS TO THIS STACK!!

TEJASHome is not a place to store things, but a place for navigating to other places where things are already stored, or should be. This is the only stack to which cards should NEVER be added.

TEJASHome Stack - Deleting Cards

DO NOT DELETE ANY CARDS FROM THIS STACK!

There are only two cards in this stack: the TEJASHome card and the TEJAS Stackware Bibliography card.

**The TEJASHome card provides your navigation 'home base.'
The TEJAS Stackware Bibliography card lists, for traceability and accreditation, the software and documents used to write this stack system.**

Both cards are important to TEJAS' overall working and are protected by a HyperTalk script. This script will intercept the 'Delete Card' and 'Cut Card' menu commands if issued, and will give you the message "Cannot delete or cut TEJASHome cards!" with a warning tone.

Moral: Don't mess with TEJASHome!

TEJASHome Stack - Card Backgrounds

There are two different backgrounds in these stacks. By specific name:

TEJASHome.bg: background for the TEJASHome card. Different cards for each technology. No primary information fields; thirteen visible card buttons of different types, one visible shadow card field labeled "Owner."

Bibliography.bg: specialized, for the Bibliography Card only. Updated only by the TEJAS Editor; lists software and references (handbooks, documents, 'how to' books, etc.) used in compiling the TEJAS stacks.

TEJASHome Stack - Information Fields

THERE ARE NO INFORMATION FIELDS IN THIS STACK.

This is the only stack within TEJAS for which this is true because it is the only stack whose purpose is purely navigation and acknowledgement, not data transfer, analysis, or reference compilation.

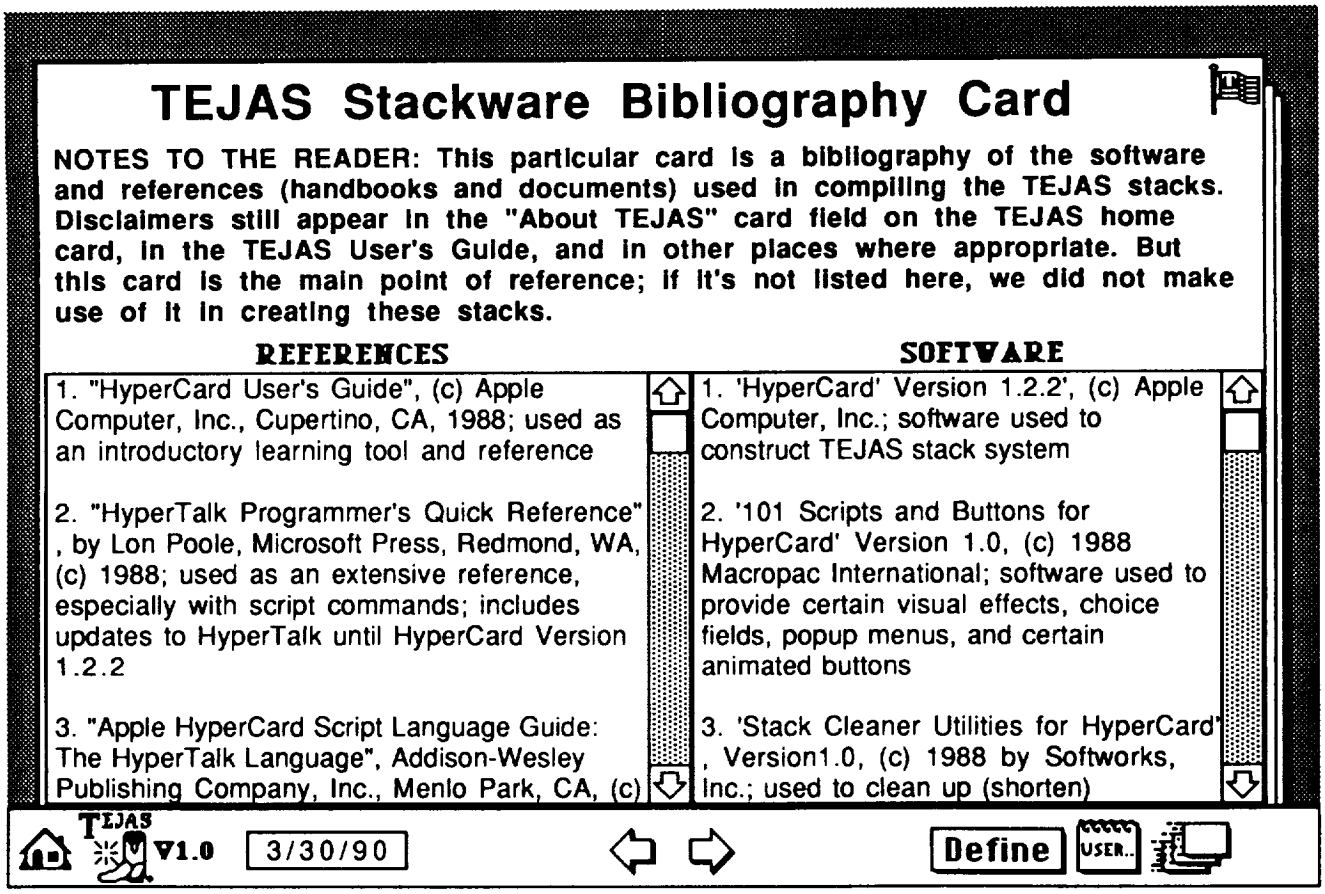
TEJASHome Stack - Buttons

Labeled icon buttons on the TEJASHome card represent each stack in TEJAS. These same icon buttons are also found in the upper left corner of every card in the stack they represent (see 'NOTE', below). They therefore help you to instantly identify a stack that you may have just entered.

The buttons use different icons to make them instantly recognizable: diamonds for analysis stacks, cubes for primitives, etc. They are separated into two sides of the card: Telerobotics on the left, EVA on the right. This is an arbitrary arrangement.

The buttons have different functions within their stacks, but here they serve only one purpose: to take you instantly to the first card of that stack.

NOTE: the TEJAS Help button **is found ONLY on this TEJASHome card, nowhere else in TEJAS. TEJAS Help is accessed from the stacks via the 'TEJAS boot' button's pop-up menu (see Help section 6.2).**



TEJASHome Stack - Stackware Bibliography Card

The second (and last) card of the TEJASHome stack lists the software (programs) and references (books, articles, etc.) used in the creation of TEJAS Version 1.0. They are provided here for accountability. Their appearance here should not be considered an endorsement; and this software is not distributed for profit. By using the same software and documents, you can create equally powerful HyperCard applications.

HyperCard itself (up to Version 1.2.5) has certain limitations that the TEJAS Editor opted to accept in order benefit from HyperCard's wide compatibility and availability. Among the limitations are a lack of color, a single non-resizable window, a complete lack of pop-up menus, etc. Many of these limitations have been surpassed by commercial HyperTalk scriptwriters in programs such as the ones listed. TEJAS used certain HyperTalk scripts and resources from these programs to 'push the envelope' of HyperCard enough to get the job done. There are hundreds of HyperTalk applications available that can provide such enhancements.

Section 7.2 – Glossary
and
Section 7.3 – Acronyms
(Not available in Miniguide)

Section 7.4

User Instructions - EVAPrimitives Stack

EVAPrimitives Help Menu

Menu 1 of 1

7.4 User Instructions

Background:

- ☐ 7.4.1 General Information
- ☐ 7.4.2 The User's Role
- ☐ 7.4.3 Changing the Standard
- ☐ 7.4.4 Adding Cards
- ☐ 7.4.5 Deleting Cards

Unique!

Generic Task Primitives:

- ☐ 7.4.6 Definition
- ☐ 7.4.7 Development
- ☐ 7.4.8 Conclusions
- ☐ 7.4.9 Building Specific from Generic Primitives

Stack-Specific Help:

- ☐ 7.4.10 Card Backgrounds
- ☐ 7.4.11 Information Fields
- ☐ 7.4.12 Buttons

Unique!

- ☐ 7.4.13 Relating EVA and Telerobot Primitives
- ☐ 7.4.14 Parsing Scheme Card
- ☐ 7.4.15 Menu Builder Card
- ☐ 7.4.16 Contributions Card

INSTRUCTIONS:
Click ☐ box to access section;
Click arrows to page through Help stack;
Click 'T-flag' to return to point of origin.

TEJAS V1.0 | 3/30/90 | Help Menu | Define

EVA Primitives — Explanation Card

Syntax | Source

Definition, Notes etc. | History

This field is available to the researcher to write the final definition of the primitive as they understand it. The interim definition (and any comments received on it) should go in the History field, accessible by pressing the 'History' button above.

Like Verbs:

Antonym

This space is left blank to allow display of other, related information stored in hidden fields, e.g. graphics, text, etc. The History field is one such. Data on specific tools, objects (such as connectors, bolts etc.) and specifications (torques, temps, pressures etc.) can be displayed by means of a new button if desired.

TEJAS V1.0 | 3/30/90 | Find Verb | Define

EVAPrimitives Stack - General Information

The EVAPrimitives stack serves as repositories for a final set of generic task primitives for crew extravehicular activity. Each card has one primitive verb, a definition, a syntax, like (similar) verbs (NOT synonyms; see Help section 7.4.11), an antonym, and a field showing that primitive's evolution.

With relational hypermedia, you can add new or improved fields, or graphics, animation, and sound, if necessary, to completely convey the idea. Any card copied into any other stack would automatically include these functions.

The EVAPrimitives and TelePrimitives stacks are intended as master lists of GENERIC primitives for the nationwide EVA and telerobotics task analysis communities. TEJAS also accesses them during task analysis via a menu (see 'Task Analysis in TEJAS,' Help section 8.1.6). From these generic primitive 'roots,' SPECIFIC primitives evolve by specifying the arguments according to that specific task, leaving the master lists intact.

EVAPrimitives Stack - The User's Role

This stack is meant to provide a standardized reference for many analyses. There are dozens of primitives involved in EVA and telerobotic activities. Scripting on-orbit tasks requires specific primitives derived from these lists (see Help section 7.4.9). Relating telerobotics to crew-EVA is possible through the use of these primitives stacks, but it requires VALID reference data. All users benefit from a standardized set. Please help make this stack complete and accurate by performing three very important operations:

1. CHECK for missing primitives (especially EVA verbs already in use), then add them (see 'Adding Cards,' Help section 7.4.4). Version 1.0 of this stack will not be a complete list.
2. EXAMINE all the information fields. Make changes if necessary (see 'Changing the Standard,' Help section 7.4.3), but BE CERTAIN to keep the original Version 1.0 as a backup.
3. ADD comments or suggestions in the User Notes field for each primitive already in the stack.

EVAPrimitives Stack - Changing the Standard

You can make changes in any stack information field, since none of the fields are locked. There are different mechanisms for entering data (see the 'Information Fields' Help cards in this section).

Make changes if you do not agree with the data on a particular primitive, but BE CERTAIN to justify those changes in the User Notes field AND to update the Source field for traceability.

TEJAS will track all changes by updating the Date field, and setting the TEJAS Version field to "V1.0+". When you feel you have compiled sufficient changes, send the updated stack to the TEJAS Editor. All changes and comments will be automatically retrieved and reviewed for incorporation into the next version of this stack. Remember that any time you change this reference stack data, it is no longer the Version 1.0 release but a modification of it (hence the "+"). Keep your original Version 1.0 stacks safely archived.

EVAPrimitives Stack - Adding Cards

Before adding a new card, ensure a CLEAR NEED, i.e., check that the concept is not already covered by an existing primitive in the stack.

To add the new verb primitive:

1. Go to the Explanation card (first card in the stack).
2. Select 'New Card' from the Edit menu. A blank card will appear.
3. Fill out ALL the information fields, with comments in the User Notes field to explain why the primitive was suggested.
4. Select 'Card Info...' from the Objects menu. Type the verb as the card name. This ensures that the new verb will appear on the primitives menu.
5. Either cut and paste the new card alphabetically by verb, or sort.

NOTE: New verbs will not appear in the EVAPrimitives verb menus until the Menu Builder card's 'Rebuild' button has been activated (see explanation of the Menu Builder Card, Help section 7.4.15).

EVAPrimitives Stack - Deleting Cards

DO NOT DELETE ANY CARDS FROM THIS STACK!

Any primitive you find objectionable may not be so to others; compromise was necessary to reach the current stack and will continue to be necessary to evolve a truly complete, integrated primitives set for the EVA community.

Primitives that are defined as "deleted" are in fact still archived on cards in the stacks. They have only been omitted from the integrated set of EVAPrimitives; their History fields reflect why (see Help section 7.4.11). TEJAS will prevent you from deleting any primitives. Instead, state your reasons for deletion in the User Notes, along with any other comments.

Remember that the primitives lists are like a spiderweb; everything is connected to something else. THINK IT THROUGH. What would deleting this verb do to the complete set? Could the definition just be changed? How does this affect relating EVAPrimitives to TelePrimitives?

Task Primitives - Definition

Two kinds of primitives exist: generic and specific. Their definitions are:

Primitive, Generic: The smallest descriptive task component for a crewmember or telerobot work system performing work, involving a subject (crew, system, or subsystem), an action VERB, and undefined arguments in a consistent syntax. Example Verbs: GRASP, TRANSLATE, ATTACH, VERIFY, etc.

Primitive, Specific: The smallest descriptive task component for a crewmember or telerobot work system performing work, involving a subject (EV1, EV2, or a telerobot work system or subsystem), an action VERB, the object of that action, and external factors, all defined as specific arguments connected by prepositions, and evolved (in the TEJAS stack system) from generic primitives. Examples: FTS GRASP wrench; EV2 TRANSLATE to MMU; EV1 ATTACH tether to slidewire; IV1 VERIFY RMS clear of obstructions, etc.

Task Primitives - Development

The steps in the development of this Version 1.0 release are illustrated on the next card and detailed below. Follow the process bars (..... and ~~~~~) to see the development. Development steps were:

- Generic task primitives included in this EVAPrimitives stack first compiled from an initial set of published documents (first boxed list)

- Review release of EVAPrimitives and TelePrimitives stacks to members of the EVA and Telerobotics communities (first and cubes)

- Comments received from the primitives reviewers (feedback loop)

- Review and resolution of all comments to the review stacks. Primitives cards modified; all comments and final notes archived in History field.

- TEJAS Version 1.0 primitives stacks released (second and cubes)

TEJAS V1.0 | 3/30/90 | Help Menu | Define | USER...

Task Primitives - Development

- "Task Ranking for the Telerobot Demonstration", JPL/SRI Report 1988: preliminary telerobot primitives (Teleprimitives) & EVA primitives lists

- "Advanced Robotics for In-Space Vehicle Processing" (Interim), J.H. Smith et al JPL, 5/89: expanded teleprimitives & EVAprimitives lists

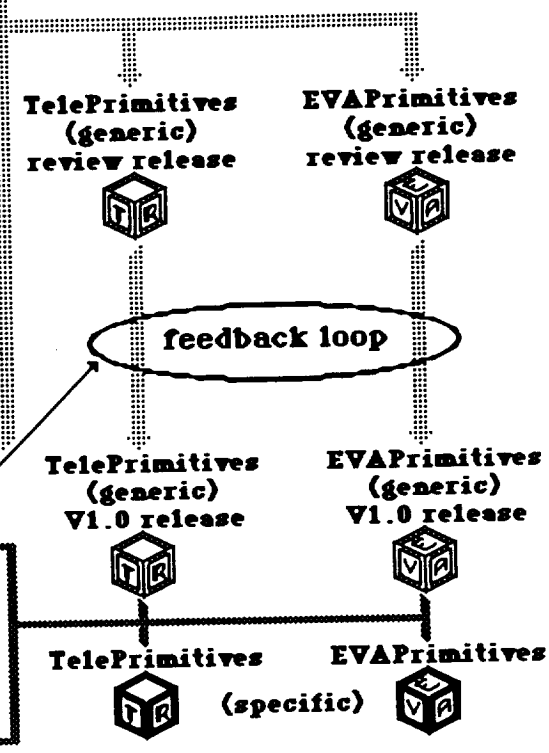
- "Flight Telerobotic Servicer Task Analysis Methodology", GSFC MUT 4/89: expanded teleprimitives list

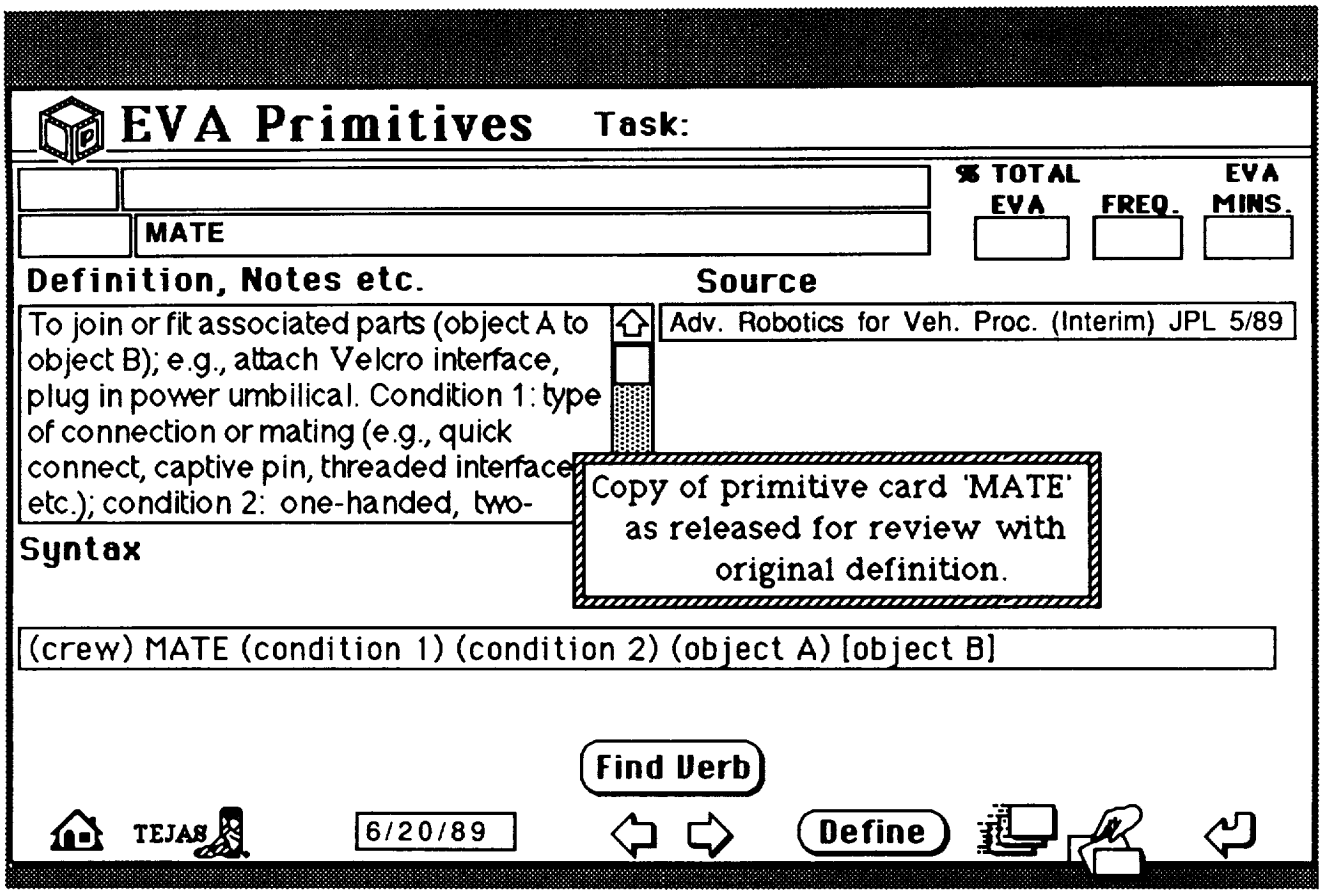
- "Telerobotic Application to EVA Activities", MDAC 10/88: teleprimitives, EVAprimitives, written links

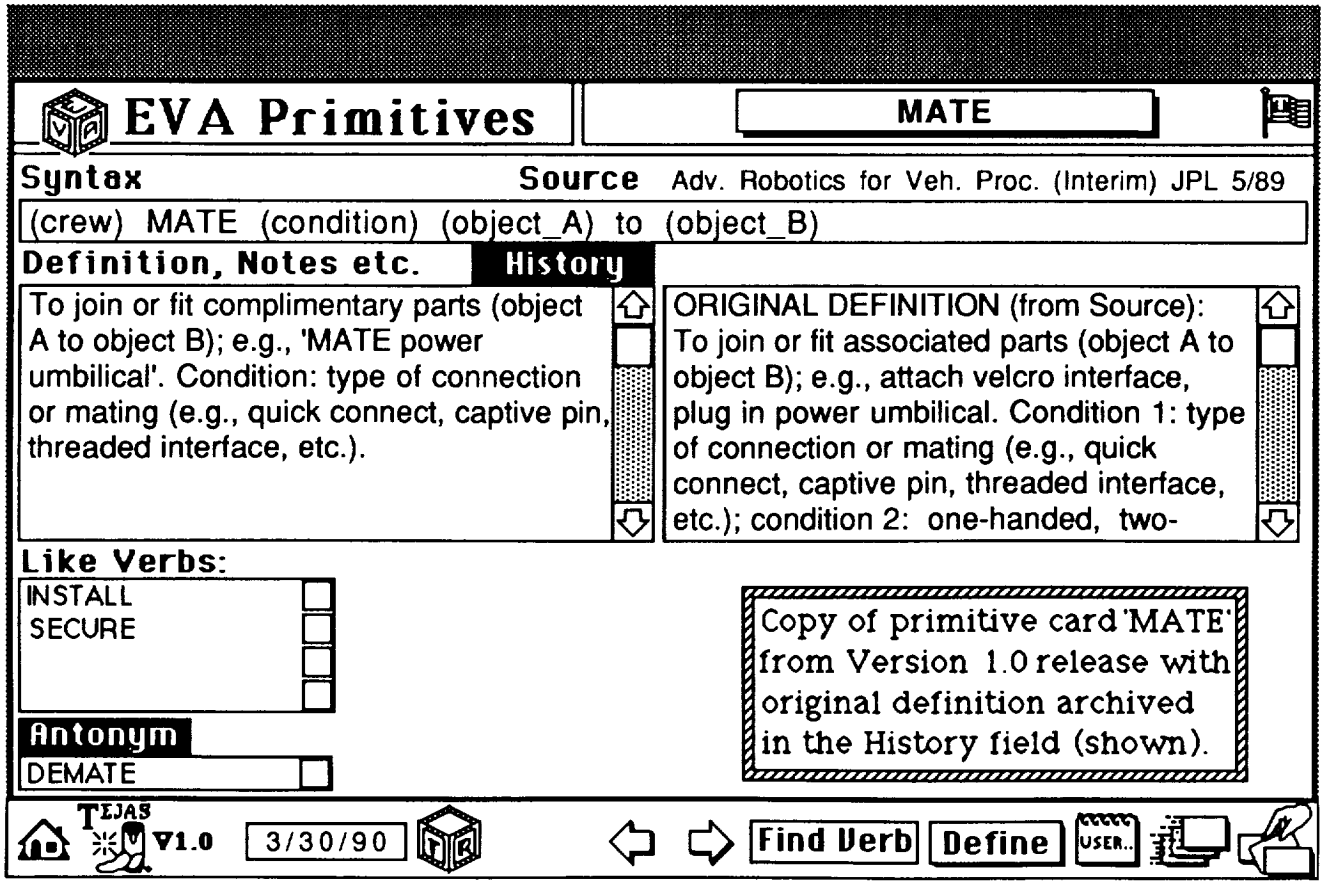
- Comments from EVA and telerobotics communities on TelePrimitives & EVAPrimitives review lists

- J.H. Smith "ARISVP": specific teleprimitives derived from TEJAS pre-release list

- "Vehicle Processing Operations Data Collection Set (VPOD) " CTA Inc. & LaRC 1989: specific teleprimitives derived from TEJAS pre-release list




EVA Primitives
Task:
% TOTAL EVA
FREQ.
EVA MINS.
MATE
Definition, Notes etc.
Source
To join or fit associated parts (object A to object B); e.g., attach Velcro interface, plug in power umbilical. Condition 1: type of connection or mating (e.g., quick connect, captive pin, threaded interface etc.); condition 2: one-handed, two-
Adv. Robotics for Veh. Proc. (Interim) JPL 5/89
Copy of primitive card 'MATE' as released for review with original definition.
Syntax
(crew) MATE (condition 1) (condition 2) (object A) [object B]
Find Verb
TEJAS
6/20/89
Define


EVA Primitives
MATE
Syntax
Source
Adv. Robotics for Veh. Proc. (Interim) JPL 5/89
(crew) MATE (condition) (object_A) to (object_B)
Definition, Notes etc.
History
To join or fit complimentary parts (object A to object B); e.g., 'MATE power umbilical'. Condition: type of connection or mating (e.g., quick connect, captive pin, threaded interface, etc.).
ORIGINAL DEFINITION (from Source): To join or fit associated parts (object A to object B); e.g., attach velcro interface, plug in power umbilical. Condition 1: type of connection or mating (e.g., quick connect, captive pin, threaded interface, etc.); condition 2: one-handed, two-
Like Verbs:
INSTALL
SECURE
Antonym
DEMATE
Copy of primitive card 'MATE' from Version 1.0 release with original definition archived in the History field (shown).
TEJAS V1.0
3/30/90
Find Verb
Define
USER..

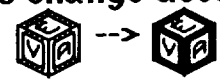
Task Primitives - Conclusions

- The basic steps of task analysis methodologies (TAMs) are similar between EVA and Telerobotics, up to the outline (see below):

1. Name the task.
2. Divide the task into subtasks; this can take several iterations. In TEJAS, all subtasks are considered to be 'tasks.'
3. Write a prose description of the task.
4. State the assumptions of the task: about task sequencing, lighting, environment, geometry, objects to be handled, tools used, etc.
5. State the open issues – things not decided or known.
6. Develop an outline (no set format) of the steps in the task.
7. Build the detailed task script of specific primitives.
8. Perform detailed analysis on this task script and attendant data.

At step 8, the approaches appear to diverge. The number and name of hierarchical levels in their detailed analysis varies by TAM.

Task Primitives - Conclusions

- Generic primitives have generic arguments. Specific primitives are derived from generic primitives by specifying their generic arguments (see Help section 7.4.9). Generic primitives are therefore a finite set of roots; specific primitives change according to each task and are a potentially unlimited set. 

- Verb-based syntaxes for standardizing and relating generic primitives must be part of any compilation, to help automate the generic-to-specific step. Generic syntaxes will evolve into a standard form only through actual use in task analyses.

- Primitives are universal objects of task analysis, with their level set in each particular methodology. Primitives should be standardized, not the TAMs. With standardized generic primitives, all TAMs may be reconciled on an equal basis.

Task Primitives - Conclusions

- Generic EVA primitives are far more complex, but less numerous, than telerobot primitives, because a human can sense and identify, move etc. To accomplish a single EVA step, a telerobot must execute a greater number of preliminary steps, either sequentially or in parallel (depending on the microprocessor technology used). As an example, consider:

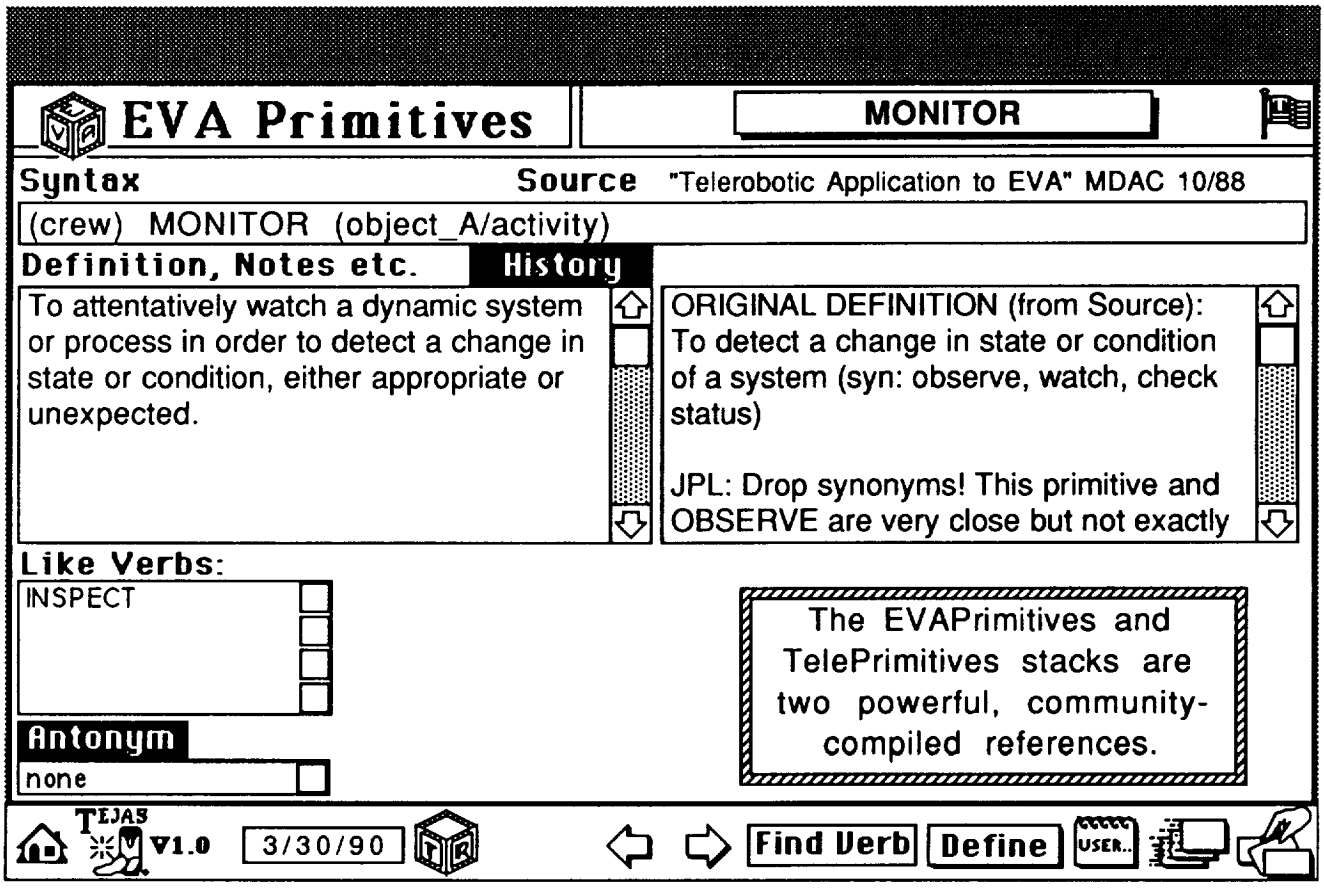
EV1 HANDOFF portable foot restraint to EV2 — **This specific EVA primitive...**

FTS ACQUIRE EV2
FTS LOCATE EV2
FTS MOVE portable foot restraint to EV2
FTS VERIFY EV2 has grasped portable foot restraint
FTS UNGRASP portable foot restraint

...may equate to this set of specific telerobot primitives.

- Relationships between EVA and telerobotics are through specific primitives, not generic primitives. These links are therefore task-dependent.

TEJAS V1.0 | 3/30/90 | Help Menu | Define | USER



Building Specific From Generic Primitives

Specific primitives are built by specifying the generic arguments of a generic primitive syntax to fit the circumstances of a particular task. The specific primitives list approximates the outline for that task (see 'Task Analysis in TEJAS,' Help section 8.1.6).

EVA Task Summary

For a specific step in the task outline...

- Prepare workstation for hydrazine refueling
- Verify that the OMV is stabilized and ready for refueling
- Couple hydrazine filler line to OMV hydrazine interface panel

EVA Task Primitives (Generic)

...retrieve the generic primitive for that action...

(crew) COUPLE (object_A) to (object_B) [with (tool)]

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Building Specific From Generic Primitives

tool | (crew) COUPLE (object_A) to (object_B) [with (tool)]

- hydrazine multipurpose tool
- hydrazine right angle clipper
- hydrazine safety wire clipper
- hydrazine spanner wrench
- hydrazine tool support brace
- Add Item
- Delete Item

...then specify each generic argument using items from a reconfigurable menu (or by hand)...

(crew) COUPLE (object_A) to (object_B) with hydrazine spanner wrench

...and after limited repetition...

EV1 COUPLE filler line to OMV hydrazine port with hydrazine spanner wrench

EVA Task Primitives (Specific)

...a specific primitive, built precisely for that task from the generic syntax, may be archived.

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EVAPrimitives Stack - Card Backgrounds

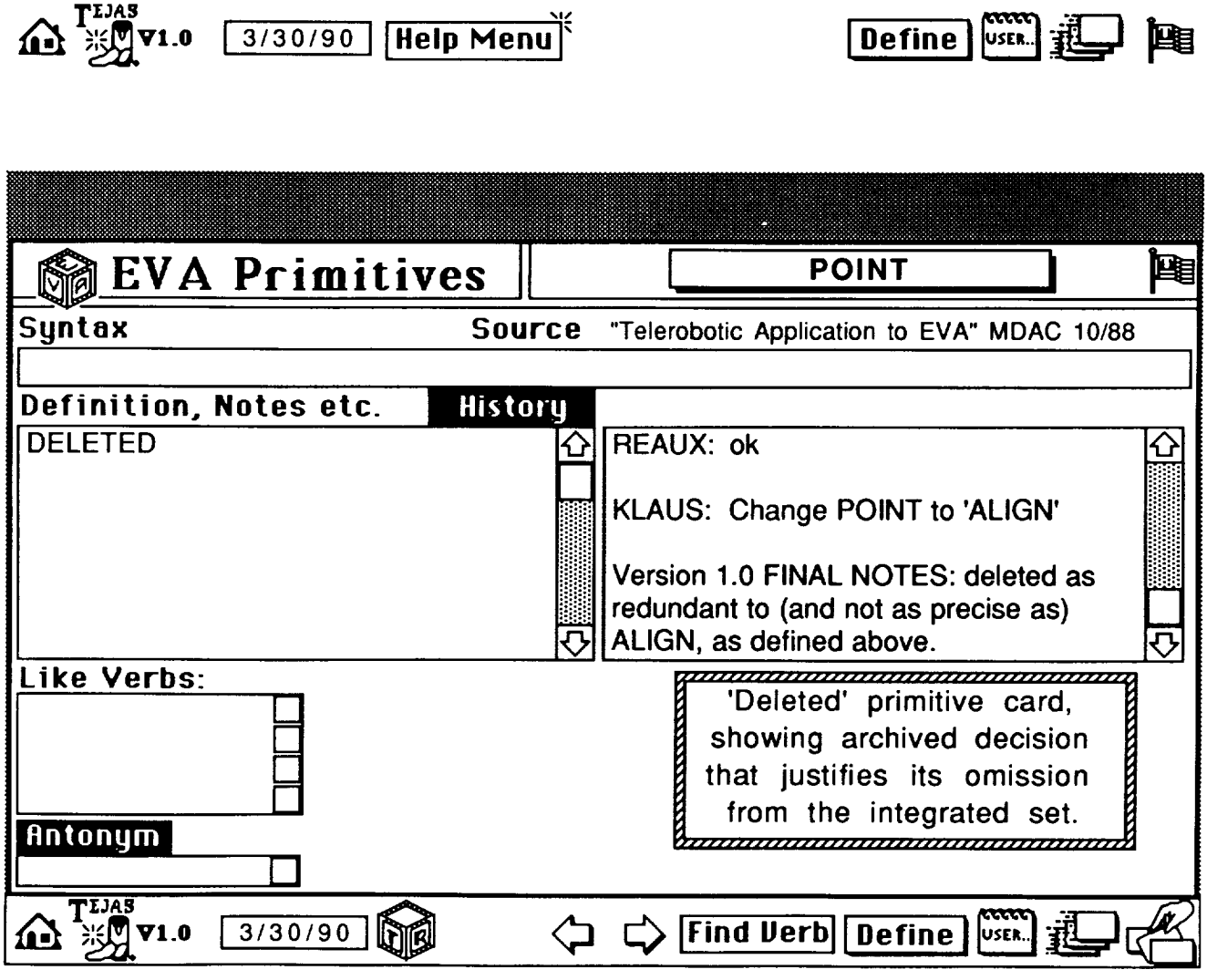
There are four different backgrounds in this stack. By specific name:

EVAPrimitives.bg – main background for this stack. Different cards for each verb primitive. Incorporates primary information fields: eight visible background fields of different types, two hidden scrolling fields.

EVAPrimsParsing.bg – specialized, for the Syntax Parsing card only. Unlocked, but a reference for all information cards in the stack. Changes are best made via the User Notes comments field (Help section 6.5).

EVAPrimsMenu.bg – specialized, for the Menu Builder Card only. Unlocked, but a reference for all information cards in the stack. Changes are best made via the User Notes comments field (Help section 6.5).

Contributions.bg – specialized, for the Contributions Card only. Unlocked.



EVAPrimitives Stack - Information Fields

There are seven information fields common to the 'EVAPrimitives.bg' background: Verb, Def/Notes, Syntax, Like Verbs, Antonym, Source, History. Field specifications are on the following cards.

If at any time, you disagree with the contents of an unlocked field, you may change it. You can change the Definition, generic Syntax, Like Verbs and Antonym if you wish, but remember that the like verbs and antonym form a kind of thesaurus; do not change them without careful consideration.

Leave locked fields and the History field alone. Make general comments in the User Notes field, either as a reminder to yourself or to communicate with the TEJAS Editor.

If you want your changes to be considered for compilation, please follow the simple conventions (e.g., verbs capitalized, generic syntax arguments in parentheses, etc.) detailed in the field specifications cards that follow.

EVAPrimitives Stack - Information Fields

Field specifications:

Verb: unlocked, unlabeled shadow field at top right. Contains one- or two-word primitive verb. One-word verbs are desirable; two-word verbs (verb plus adverb or article) are used only to differentiate between different primitives with identical verbs. First word of verb is all capital letters.

Def/Notes: unlocked, labeled scrolling field at middle left. Contains definition and notes about the verb primitive, as compiled from the original definition and changes made during the review process.

Syntax: unlocked, labeled rectangle field across top of card. Contains the suggested generic syntax for the primitive with generic arguments (in parentheses) connected by prepositions (see 'Parsing Scheme Card,' Help section 7.4.14). Both format and content can be changed; submit suggested changes to the TEJAS Editor.

EVAPrimitives Stack - Information Fields

Field specifications cont'd:

Like Verbs: unlocked, labeled rectangle field at lower left. Contains list of verbs with similar connotations to the present verb. Like Verbs ARE NOT SYNONYMS! Synonymous verbs would be redundant; however, Like Verbs are distinct, in definition and use (example: INSPECT has like verbs MONITOR, TEST and VERIFY). Pressing on the square button opposite a like verb takes you to that card.

Antonym: unlocked, labeled rectangle field beneath the Like Verbs field. Logically, only one antonym may (and should) exist, since there are no synonyms, only like verbs. Pressing on the square button opposite the verb antonym takes you to that card. If none of the primitive verbs in the stack applies as an antonym, the field will be blank. If there logically is no antonym, the field will say 'none'.

EVAPrimitives Stack - Information Fields

Field specifications cont'd:

Source: unlocked, labeled transparent field at upper right. Contains an abbreviated reference to the document or notes where the verb first came to the attention of the TEJAS project. For more definitive titles, see the Contributions Card (last card in the stack).

History: unlocked, labeled, hidden scrolling field at middle right, alongside Def/Notes. Contains "ORIGINAL DEFINITION (from Source):" for the verb primitive, notes, redlines, etc. received (with sender's name or initials) during the review process, and "Version 1.0 FINAL NOTES:" that tell how final definition evolved. Used for traceability; normally not printed. Visibility of this field is set via the History button (see Help section 7.4.12).

EVAPrimitives Stack - Buttons

There are four buttons in the 'EVAPrimitives.bg' background that access information about each verb primitive, or a related one. They are

☐ - the square buttons are used to access Like Verbs and the Antonym for each verb. Click on these to navigate to the verb closest to each button.

History - the History field is hidden, to provide a space on the right side of each card for other information (graphic, video, or other text fields, for instance). Clicking on this button highlights it and shows the field; clicking again hides the field and turns the highlighting off.

Find Verb - to find a particular verb primitive, click here. A dialog box will ask "Find what Verb?". Type it in (capitalization not required) and click OK (or press return). If not found, a message will tell you so. Try again - you may have misspelled it. Using this button is faster than scanning cards one at a time with the Next, Previous, or Show buttons.

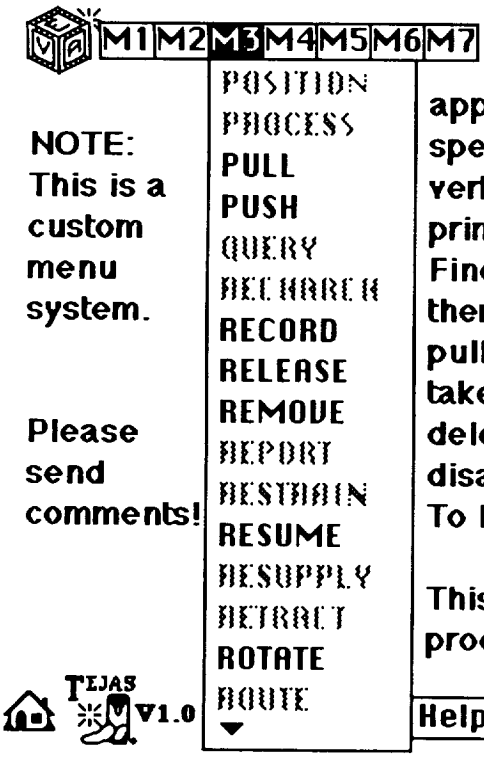
EVAPrimitives Stack - Buttons

- the 'EVAPrimitives block' button at the upper left corner of the EVAPrimitives cards is part of a customized, powerful script that creates a set of selectable menus of the verb primitives for quick navigation. The menus are updateable; they can vary with additions or deletions to the verb list. They are maintained by the 'Menu Builder' card (see Help section 7.4.15). This was a special challenge.

Pop-up menus are limited to 256 characters total. To stay within this limit, the HyperTalk script behind this button takes the total number of characters for all verbs, conservatively divides it by 220, and mathematically finds the starting and ending verbs for the number of M menus required to list all the verbs (averaging 25 verbs per menu). The script then shows that many M buttons (up to seven).

All this happens very quickly, as the first step in using the button. For the second step, go to the next card --->

EVAPrimitives Stack - Buttons



NOTE:
This is a custom menu system.

Please send comments!

Clicking and holding down on any of the M buttons immediately causes a pop-up menu to appear with primitive verbs, starting and ending as specified by the Menu Builder card. Non-selectable verbs are shadowed; they are the deleted (omitted) primitives left in the stack for traceability (use the Find Verb, Show, Next, or Previous buttons to go to them). All other 'boldface' verbs are selectable; pulling the cursor down and releasing on them will take you to that card. Releasing the mouse on a deleted verb or off the menu will cause the menu to disappear. That's all - you won't go anywhere.
To hide the M buttons, just click on again.

This process varies in speed with RAM size and processor. With the Mac SE and Plus, it is fairly slow.

TEJAS V1.0 Help Menu Define USER..

EVAPrimitives Stack - Buttons

- a corresponding 'TelePrimitives block' button is located at the BOTTOM of each primitive card. This button provides a quick way to check for the presence of that same verb in the TelePrimitives stack. Relatively few verbs are common; the telerobotics 'language' is more precise than the EVA parlance that has evolved in manned spaceflight. Common verbs generally have quite different definitions; these differences can be VERY enlightening (try this button at the EVA primitive ATTACH).

To use this button, click on it. If there IS an exact match, the script will save your place, then take you to that card in TelePrimitives. You can read it, then return to the EVA primitive by using the T-flag, or pressing 'escape'.

If the script cannot find the EXACT same verb in the other stack, it will answer "No exact match," and leave you in place. That may peak your curiosity to see just what telerobotics primitive DOES correspond (if any). You can then go to the TelePrimitives stack and search manually.

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Relating EVA and Telerobot Primitives

EVA primitives are much more complex than telerobot primitives, because humans can multitask (perform more than one function at the same time) to deal with larger chunks of tasks than telerobots can. To see this, compare the syntax parsing schemes for EVAPrimitives (Help section 7.4.14) and TelePrimitives (Help section 7.5.14).

The definition, syntax, and other information must be complete for each EVA or telerobot primitive. The syntaxes of both telerobot and EVA primitives have generic arguments that lead to a virtually infinite set of potential specific primitives.

The transformation from generic primitives (in these stacks) to specific primitives is task-dependent and takes place in the Specific Tasks stacks (e.g., EVATask.4893, EVATask.3225, etc.). For each task, a set of specific EVA primitives must be built to construct a script that follows the task outline (see 'Building Specific from Generic Primitives,' Help section 7.4.9).

Relating EVA and Telerobot Primitives

The relationship between EVA and telerobot primitives is one-to-many. That is, a single EVA primitive usually relates to a set (more than one) of telerobot primitives. TEJAS attempts to build that link in the direction EVA-> Telerobotics, because EVA primitives are better understood than telerobotics primitives (telerobotics is a much younger evolving science).

It is difficult, almost impossible, to create definite links between generic, rather than specific, EVA and telerobot primitives. There are two reasons:

- The selection of a telerobot primitive may be telerobot-dependent. For example, the RMS would RELEASE a payload or object, but a telerobot with a multifingered end effector ('hand') would UNGRASP it.

- The order and selection of telerobot primitives may depend upon the mode of operation – pure teleoperation, automated sequences, traded control, shared control, supervised autonomy, etc.

Relating EVA and Telerobot Primitives

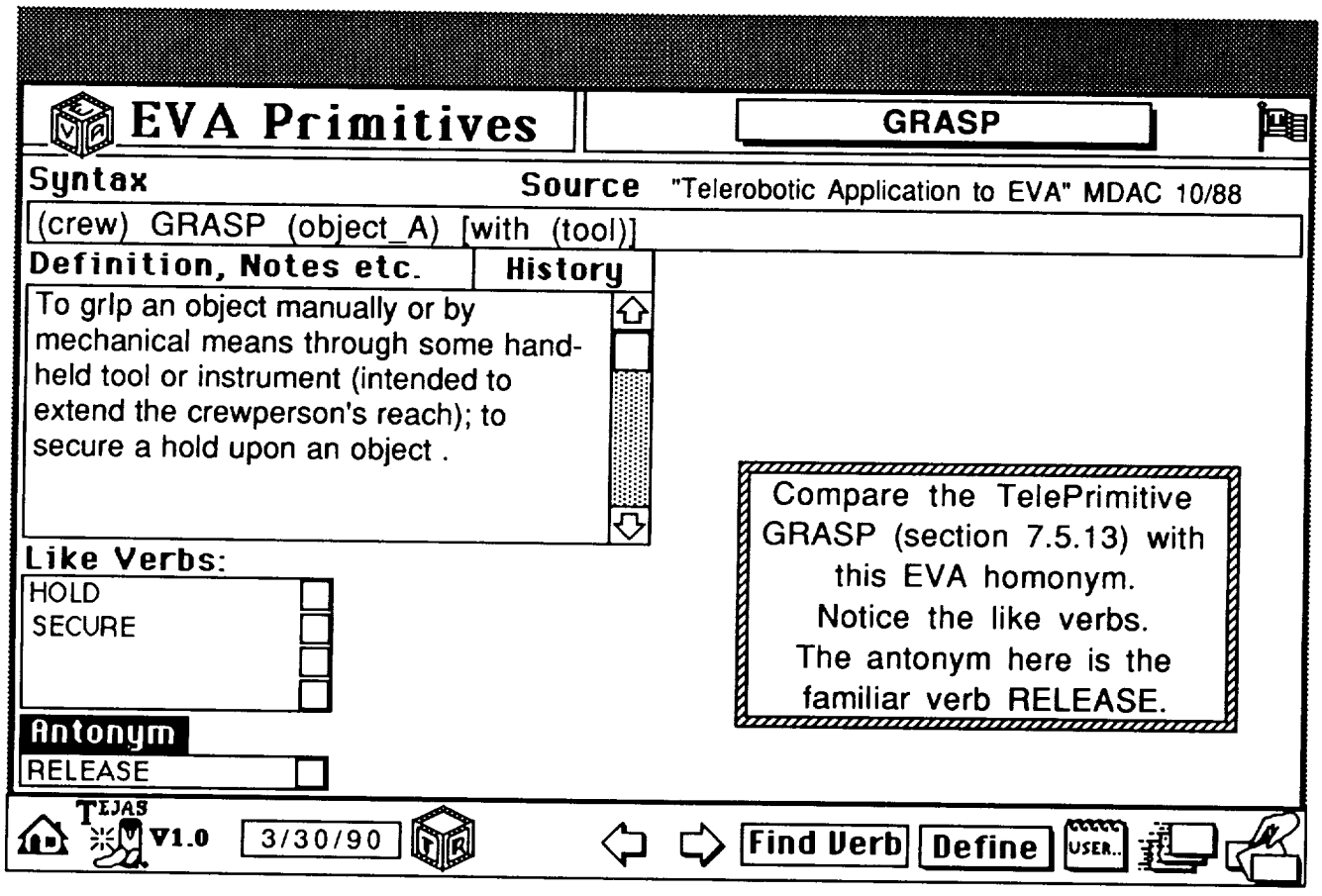
Although generic EVA and telerobot primitives may not be matched in a fixed relationship, there are clearly similarities in definition and syntax between verbs in either list. This is both intentional and desirable.

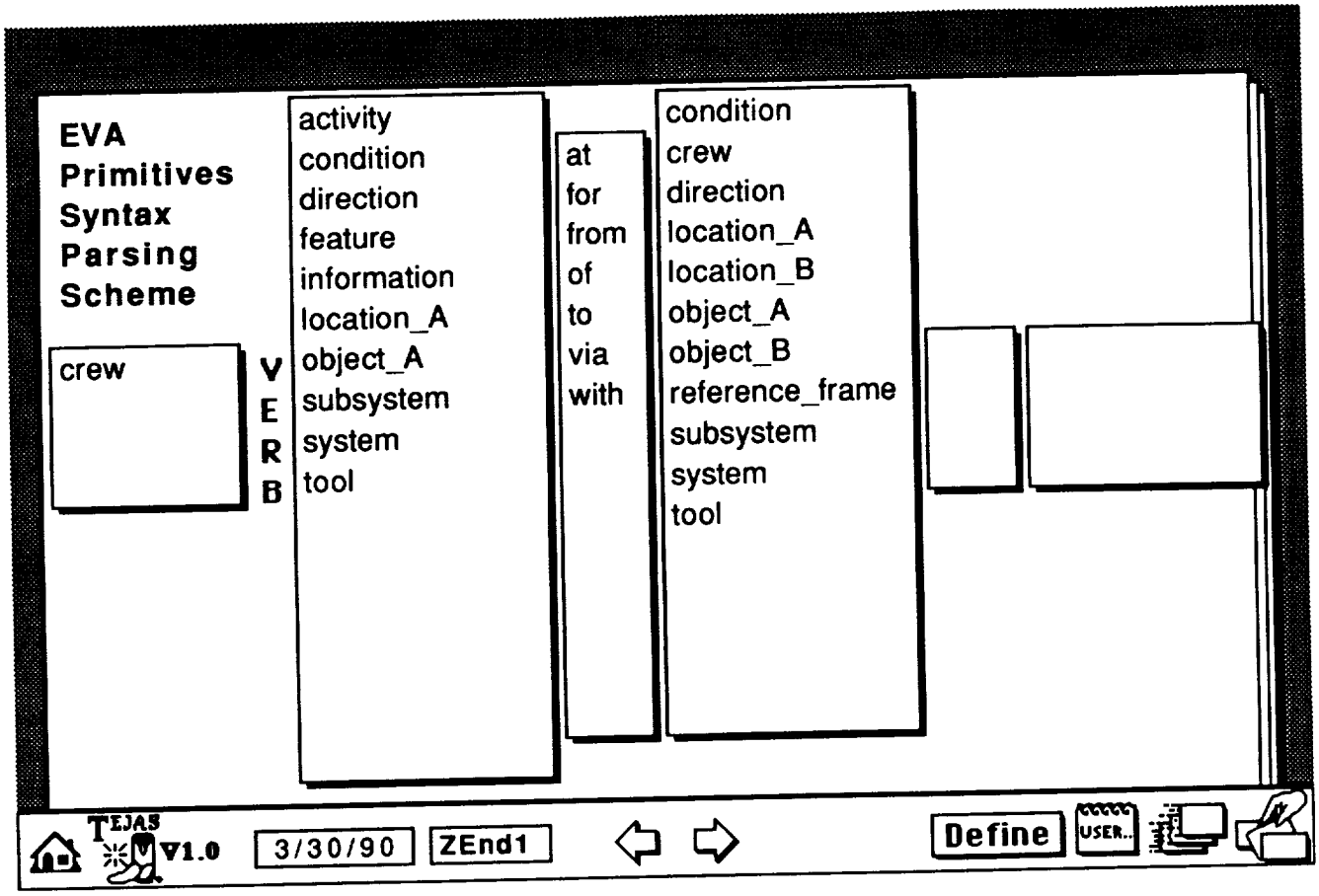
In the EVAPrimitives stack, a button has been provided (Help section 7.4.12) to seek the same verb in the complementary TelePrimitives stack. Sometimes primitives with the same verb but different meanings exist in both stacks (e.g., RELEASE). It can be instructional to see these homonyms.

With a standardized set of generic EVA and telerobot task primitives, a set of relational rules between the specific primitives that evolve from each generic list should be attainable. A researcher will be able to use these sets of rules to trade off using EVA or telerobots in a task or subtask.

Much more work needs to be done in this area. The TEJAS primitives stacks are a solid beginning, based on a cooperative effort.

TEJAS V1.0 | 3/30/90 | Help Menu | Define | USER...





EVAPrimitives Stack - Parsing Scheme Card

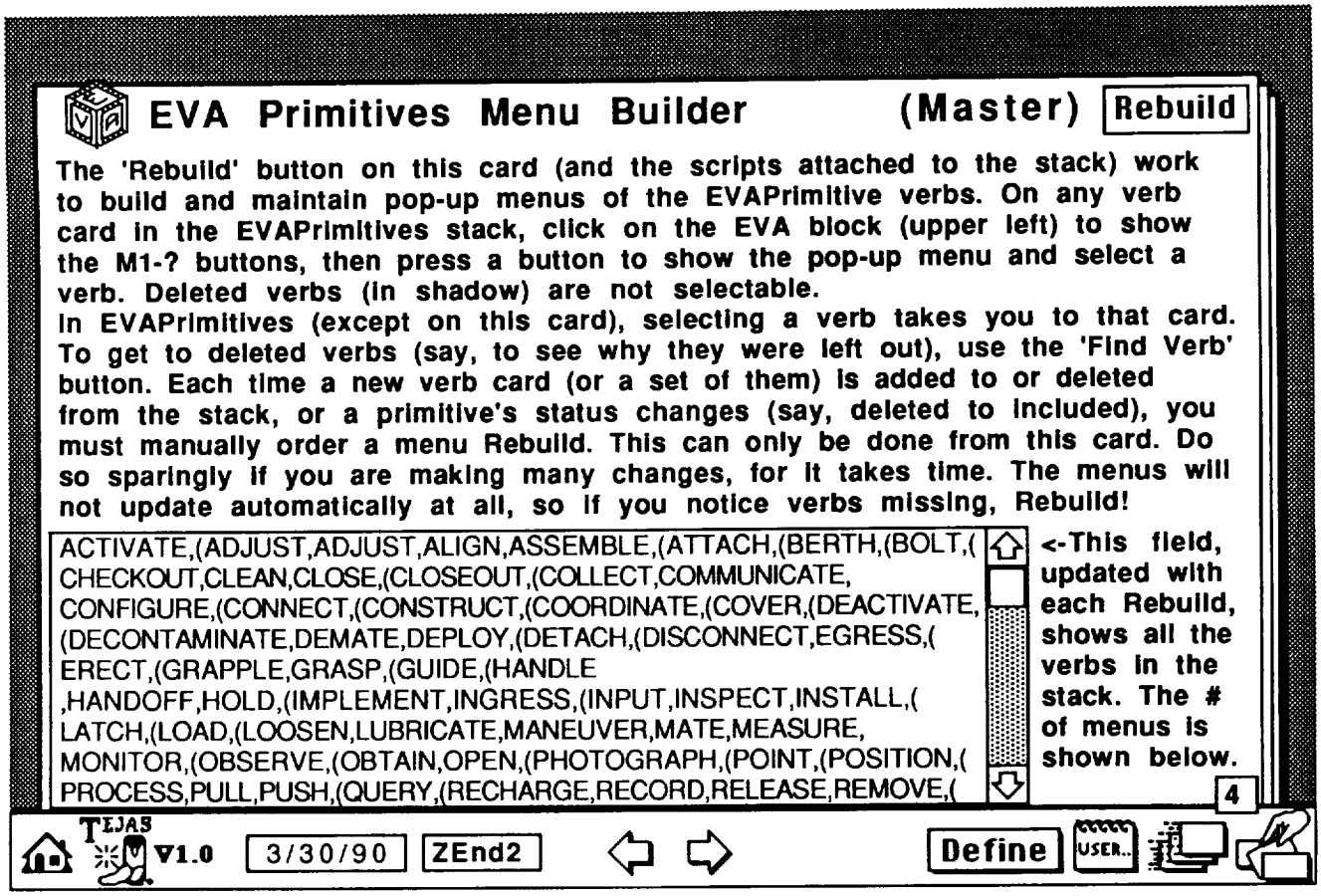
The Parsing Scheme card is found third from the last in the stack. Its sole purpose is to suggest how to build and modify GENERIC syntaxes for task primitives. It is printed in the "TEJAS User's Guide" for use as a guide. The following discussion on syntax is from "Generic Extra-Vehicular Activity (EVA) and Telerobot Task Primitives for Analysis, Design, and Integration, Version 1.0: Reference Compilation," JPL Publication 90-10. To read it, scroll down on the field below.

The syntax used in both the crew-EVA and telerobot generic primitives is important, to ensure that information needed to perform analyses on the finished specific primitives will be present in them. Let's take an example:

(subsystem) ALIGN (object_A) [with (object_B/reference_frame)]

This telerobot primitive shows the generic 'subject-VERB-predicate' syntax used with all primitives in both the EVA and telerobot primitives lists. The subject is always a noun; in the case of a telerobot, either (system) (i.e. the RMS, SPDM, or FTS) or

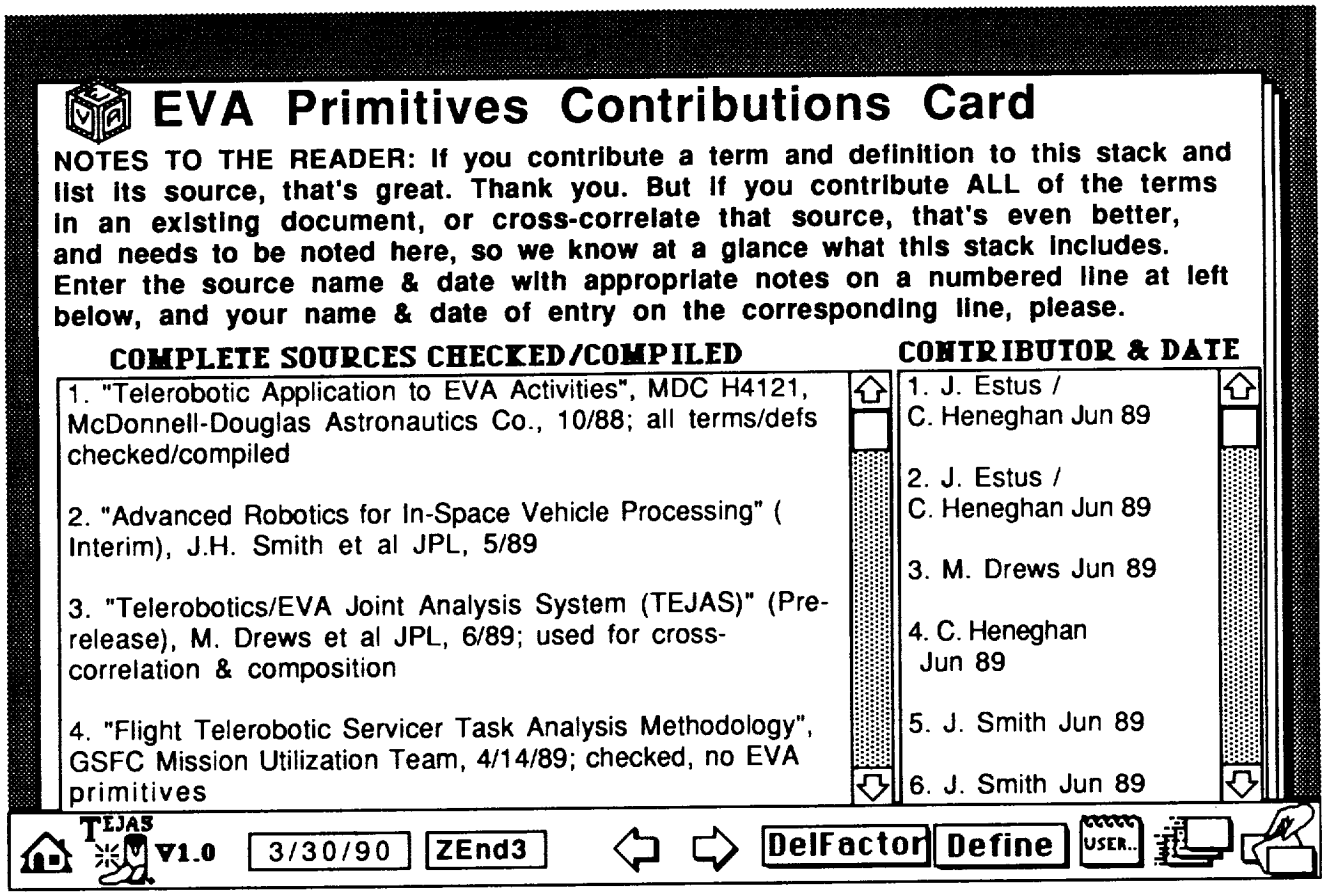
TEJAS V1.0 3/30/90 Help Menu Define USER..



EVAPrimitives Stack - Menu Builder Card

The Menu Builder card, second from the last in the stack, maintains the pop-up menus of primitive verbs available from the 'EVAPrimitives block' buttons (Help section 7.4.12). This card's visible and hidden fields and scripts work to rebuild and store these verb menus. The scripts' notation ensures that deleted verbs are non-selectable. The text on the card explains how to use it; be aware that rebuilding takes some time (longer for low-RAM Macs). Rebuild only when you have made a group of changes.

The selectable menus that this card and the scripts attached to the Primitives block and M buttons give you are more than a convenience. They provide the only place to view all the primitives in a complete list, noting which were included in the Version 1.0 integrated list and which were deleted (omitted). Viewing the list takes far less time than viewing cards one at a time or using the Show button. This facility cannot be built into other reference stacks (such as TeleTechnologies) because the number of characters in the different items makes menus impractical.



EVAPrimitives Stack - Contributions Card

7.4.16
1 of 1

The LAST card of every reference stack is like this one. When compiled, these cards form a bibliography of the TEJAS effort. The 'References' scrolling field gives a detailed list of documents, notes, or other sources that are also identified by abbreviations in the Source fields on the stack's information cards. Each reference also contains a short note about how the source was used. The corresponding numbered lines in the 'Contributor' scrolling field list who contributed the information and when. This data contibutes to the TEJAS goal of "total traceability."

With the primitives stacks, this card is particularly important. As the primitives are used, modified, and used again, this card will not be wiped clean. Instead, it will show, by the number and date of entry, the progression of compilation of community knowledge into a universal primitives stack. Please read and follow the card's instructions. If there is a reference that you think should be added but that you will not be compiling, let the TEJAS Editor know.

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Section 7.5

User Instructions - TelePrimitives Stack

TelePrimitives Help Menu

Menu 1 of 1

7.5 User Instructions

Background:

- ☐ 7.5.1 General Information
- ☐ 7.5.2 The User's Role
- ☐ 7.5.3 Changing the Standard
- ☐ 7.5.4 Adding Cards
- ☐ 7.5.5 Deleting Cards

Unique!

Generic Task Primitives:

- ☐ 7.5.6 Definition
- ☐ 7.5.7 Development
- ☐ 7.5.8 Conclusions
- ☐ 7.5.9 Building Specific from Generic Primitives

Stack-Specific Help:

- ☐ 7.5.10 Card Backgrounds
- ☐ 7.5.11 Information Fields
- ☐ 7.5.12 Buttons

Unique!

- ☐ 7.5.13 Relating EVA and Telerobot Primitives
- ☐ 7.5.14 Parsing Scheme Card
- ☐ 7.5.15 Menu Builder Card
- ☐ 7.5.16 Contributions Card

INSTRUCTIONS:
Click ☐ box to access section;
Click arrows to page through Help stack;
Click 'T-flag' to return to point of origin.

TEJAS V1.0 | 3/30/90 | Help Menu | Define | USER..

Telerobot Primitives

Explanation Card

Syntax | Source

Definition, Notes etc. | History

This field is available to the researcher to write the final definition of the primitive as they understand it. The interim definition (and any comments received on it) should go in the History field, accessible by pressing the 'History' button above.

~~This space is left blank to~~ allow display of other, related information stored in hidden fields, e.g. graphics, text, etc. The History field is one such. Data on specific tools, objects (such as connectors, bolts etc) and specifications (torques, temps, pressures etc.) can be displayed by means of a new button if desired.

Like Verbs:

Antonym

S&P | CE | P&R | OI | SI

NASREM

TEJAS V1.0 | 3/30/90 | Find Verb | Define | USER..

TelePrimitives Stack - General Information

The TelePrimitives stack serves as repositories for a final set of generic task primitives for telerobot activity. Each card has one verb primitive, a definition, syntax, like (similar) verbs (NOT synonyms; see Help section 7.5.11), an antonym, and a field showing that primitive's evolution.

With relational hypermedia, you can add new or improved fields, or graphics, animation, and sound, if necessary, to completely convey the idea. Any card copied into any other stack would automatically include these functions.

The TelePrimitives and EVAPrimitives stacks are intended as master lists of GENERIC primitives for the nationwide telerobotics and EVA task analysis communities. TEJAS also accesses them during task analysis via a menu (see 'Task Analysis in TEJAS,' Help section 8.4.6). From these generic primitive 'roots,' SPECIFIC primitives evolve by specifying the arguments according to that specific task, leaving the master lists intact.

TelePrimitives Stack - The User's Role

This stack is meant to provide a standardized reference for many analyses. There are dozens of primitives involved in telerobotic and EVA activities. Scripting on-orbit tasks requires specific primitives derived from these lists (see Help section 7.5.9). Relating telerobotics to crew-EVA is possible through the use of these primitives stacks, but it requires VALID reference data. All users benefit from a standardized set. Please help make this stack complete and accurate by performing three very important operations:

1. CHECK for missing primitives (especially telerobot verbs already in use), then add them (see 'Adding Cards,' Help section 7.5.4). Version 1.0 of this stack will not be a complete list.
2. EXAMINE all the information fields. Make changes if necessary (see 'Changing the Standard,' Help section 7.5.3), but BE CERTAIN to keep the original Version 1.0 as a backup.
3. ADD comments or suggestions in the User Notes field for each primitive already in the stack.

TelePrimitives Stack - Changing the Standard

You can make changes in any stack information field, since none of the fields are locked. There are different mechanisms for entering data (see the 'Information Fields' Help cards in this section).

Make changes if you do not agree with the data on a particular primitive, but BE CERTAIN to justify those changes in the User Notes field AND to update the Source field for traceability.

TEJAS will track all changes by updating the Date field, and setting the TEJAS Version field to "V1.0+". When you feel you have compiled sufficient changes, send the updated stack to the TEJAS Editor. All changes and comments will be automatically retrieved and reviewed for incorporation into the next version of this stack. Remember that any time you change this reference stack data, it is no longer the Version 1.0 release but a modification of it (hence the "+"). Keep your original Version 1.0 stacks safely archived.

TelePrimitives Stack - Adding Cards

Before adding a new card, ensure a CLEAR NEED, i.e., check that the concept is not already covered by an existing primitive in the stack.

To add the new verb primitive:

1. Go to the Explanation card (first card in the stack).
2. Select 'New Card' from the Edit menu. A blank card will appear.
3. Fill out ALL the information fields, with comments in the User Notes field to explain why the primitive was suggested.
4. Select 'Card Info...' from the Objects menu. Type the verb as the card name. This ensures that the new verb will appear on the primitives menu.
5. Either cut and paste the new card alphabetically by verb, or sort.

NOTE: New verbs will not appear in the TelePrimitives verb menus until the Menu Builder card's 'Rebuild' button has been activated (see explanation of the Menu Builder Card, Help section 7.5.15).

TelePrimitives Stack - Deleting Cards

DO NOT DELETE ANY CARDS FROM THIS STACK!

Any primitive you find objectionable may not be so to others; compromise was necessary to reach the current stack and will continue to help evolve a truly complete, integrated primitives set for the telerobotics community.

Primitives that are defined as "deleted" are in fact still archived on cards in the stacks. They have only been omitted from the integrated set of TelePrimitives; their History fields reflect why (see Help section 7.5.11). TEJAS will prevent you from deleting any primitives. Instead, state your reasons for deletion in the User Notes, along with any other comments.

Remember that the primitives lists are like a spiderweb; everything is connected to something else. THINK IT THROUGH. What would deleting this verb do to the complete set? Could the definition just be changed? How does this affect relating TelePrimitives to EVAPrimitives?

Task Primitives - Definition

Two kinds of primitives exist: generic and specific. Their definitions are:

Primitive, Generic: The smallest descriptive task component for a crewmember or telerobot work system performing work, involving a subject (crew, system, or subsystem), an action VERB, and undefined arguments in a consistent syntax. Example Verbs: GRASP, TRANSLATE, ATTACH, VERIFY, etc.

Primitive, Specific: The smallest descriptive task component for a crewmember or telerobot work system performing work, involving a subject (EV1, EV2, or a telerobot work system or subsystem), an action VERB, the object of that action, and external factors, all defined as specific arguments connected by prepositions, and evolved (in the TEJAS stack system) from generic primitives. Examples: FTS GRASP wrench; EV2 TRANSLATE to MMU; EV1 ATTACH tether to slidewire; IV1 VERIFY RMS clear of obstructions, etc.

Task Primitives - Development

The steps in the development of this Version 1.0 release are illustrated on the next card and detailed below. Follow the process bars (..... and ~~~~~) to see the development. Development steps were:

- Generic task primitives included in this TelePrimitives stack first compiled from an initial set of published documents (first boxed list)

- Review release of EVAPrimitives and TelePrimitives stacks to members of the EVA and Telerobotics communities (first TR and EVA cubes)

- Comments received from the primitives reviewers (feedback loop)

- Review and resolution of all comments to the review stacks. Primitives cards modified; all comments and final notes archived in History field.

- TEJAS Version 1.0 primitives stacks released (second TR and EVA cubes)

TEJAS V1.0 | 3/30/90 | Help Menu | Define | USER...

Task Primitives - Development

- "Task Ranking for the Telerobot Demonstration", JPL/SRI Report 1988: preliminary telerobot primitives (Teleprimitives) & EVA primitives lists

- "Advanced Robotics for In-Space Vehicle Processing" (Interim), J.H. Smith et al JPL, 5/89: expanded teleprimitives & EVAprimitives lists

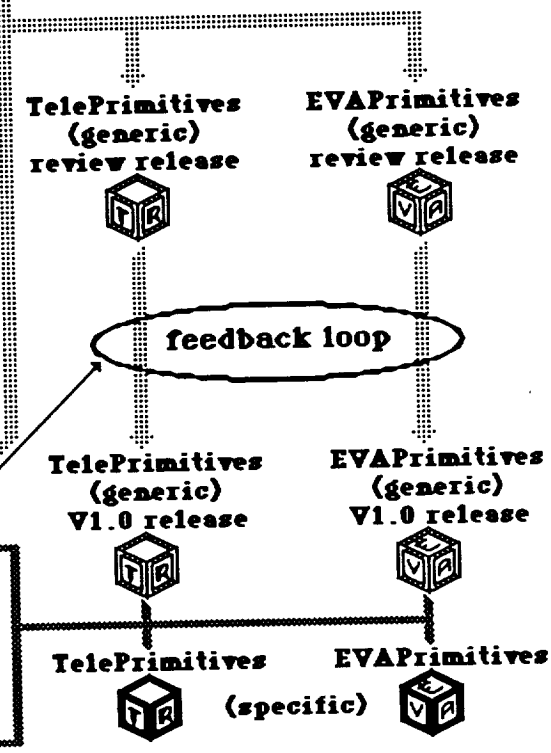
- "Flight Telerobotic Servicer Task Analysis Methodology", GSFC MUT 4/89: expanded teleprimitives list

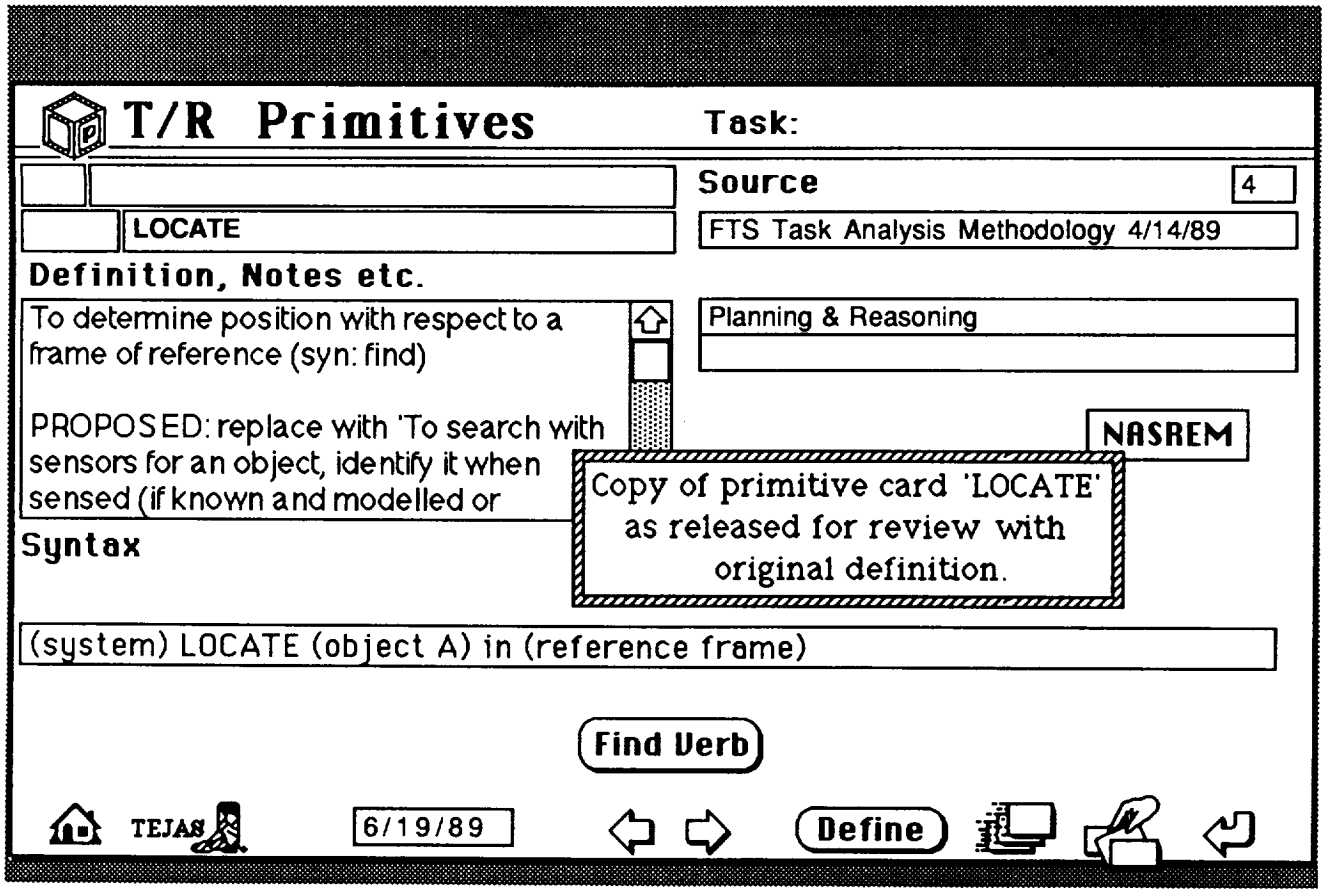
- "Telerobotic Application to EVA Activities", MDAC 10/88: teleprimitives, EVAprimitives, written links

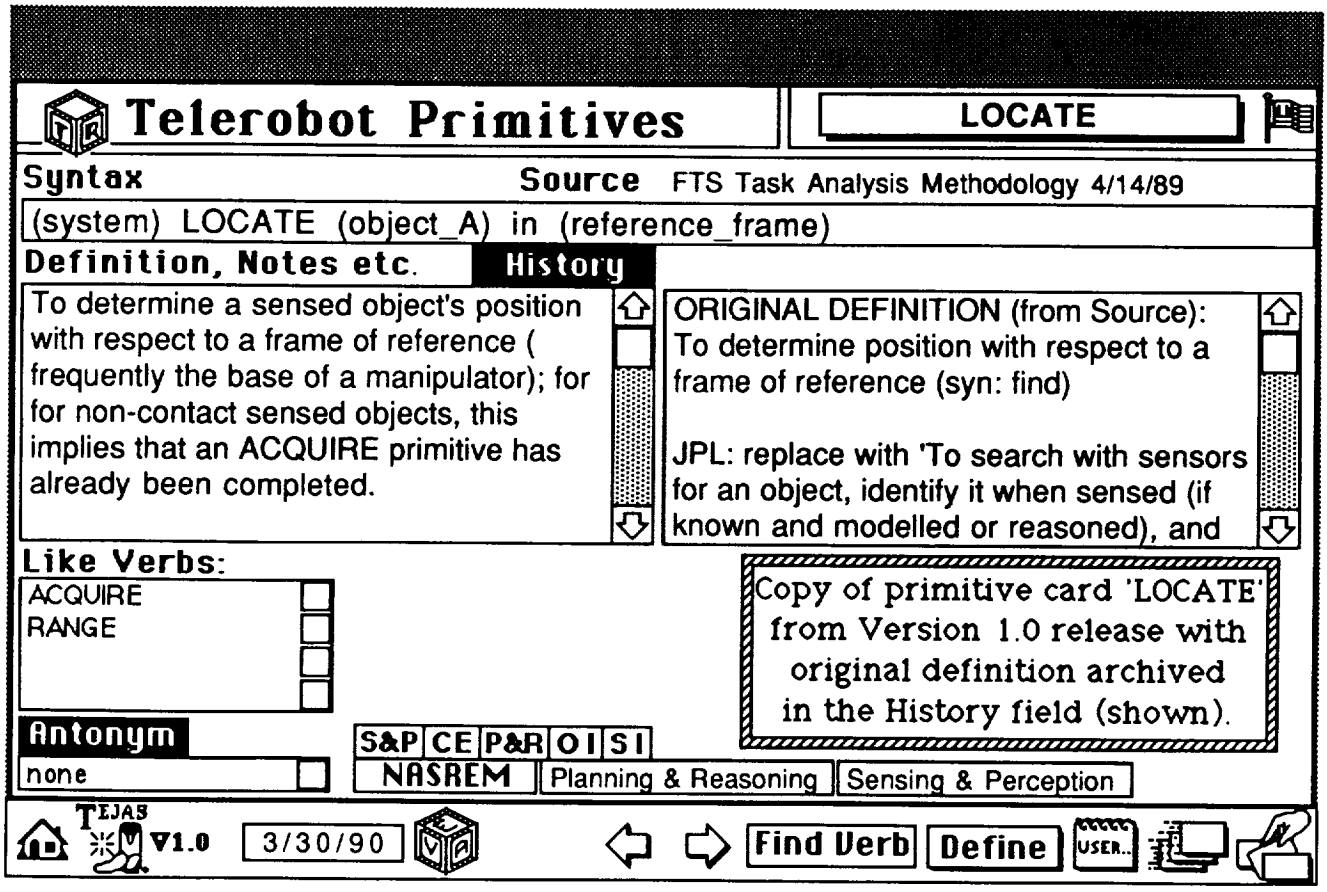
- Comments from EVA and telerobotics communities on TelePrimitives & EVAPrimitives review lists

- J.H. Smith "ARISVP": specific teleprimitives derived from TEJAS pre-release list

- "Vehicle Processing Operations Data Collection Set (VPOD) " CTA Inc. & LaRC 1989: specific teleprimitives derived from TEJAS pre-release list




T/R Primitives
Task:
Source
4
LOCATE
FTS Task Analysis Methodology 4/14/89
Definition, Notes etc.
To determine position with respect to a frame of reference (syn: find)
PROPOSED: replace with 'To search with sensors for an object, identify it when sensed (if known and modelled or
Planning & Reasoning
NASREM
Copy of primitive card 'LOCATE' as released for review with original definition.
Syntax
(system) LOCATE (object A) in (reference frame)
Find Verb
TEJAS
6/19/89
Define


Telerobot Primitives
LOCATE
Syntax
Source FTS Task Analysis Methodology 4/14/89
(system) LOCATE (object_A) in (reference_frame)
Definition, Notes etc.
History
To determine a sensed object's position with respect to a frame of reference (frequently the base of a manipulator); for for non-contact sensed objects, this implies that an ACQUIRE primitive has already been completed.
ORIGINAL DEFINITION (from Source): To determine position with respect to a frame of reference (syn: find)
JPL: replace with 'To search with sensors for an object, identify it when sensed (if known and modelled or reasoned), and
Like Verbs:
ACQUIRE
RANGE
Copy of primitive card 'LOCATE' from Version 1.0 release with original definition archived in the History field (shown).
Antonym
none
S&P CE P&R OI SI
NASREM
Planning & Reasoning
Sensing & Perception
TEJAS V1.0
3/30/90
Find Verb
Define
USER

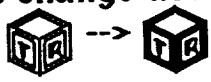
Task Primitives - Conclusions

- The basic steps of task analysis methodologies (TAMs) are similar between EVA and Telerobotics, up to the outline (see below):

1. Name the task.
2. Divide the task into subtasks; this can take several iterations. In TEJAS, all subtasks are considered to be 'tasks.'
3. Write a prose description of the task.
4. State the assumptions of the task: about task sequencing, lighting, environment, geometry, objects to be handled, tools used, etc.
5. State the open issues – things not decided or known.
6. Develop an outline (no set format) of the steps in the task.
7. Build the detailed task script of specific primitives.
8. Perform detailed analysis on this task script and attendant data.

At step 7, the approaches appear to diverge. The number and name of hierarchical levels in their detailed analysis varies by TAM.

Task Primitives - Conclusions

- Generic primitives have generic arguments. Specific primitives are derived from generic primitives by specifying their generic arguments (see Help section 7.5.9). Generic primitives are therefore a finite set of roots; specific primitives change according to each task and are a potentially unlimited set. 

- Verb-based syntaxes for standardizing and relating generic primitives must be part of any compilation, to help automate the generic-to-specific step. Generic syntaxes will evolve into a standard form only through actual use in task analyses.

- Primitives are universal objects of task analysis, with their level set in each particular methodology. Primitives should be standardized, not the TAMs. With standardized generic primitives, all TAMs may be reconciled on an equal basis.

Task Primitives - Conclusions

- Generic EVA primitives are far more complex, but less numerous, than telerobot primitives, because a human can sense and identify, move etc. To accomplish a single EVA step, a telerobot must execute a greater number of preliminary steps, either sequentially or in parallel (depending on the microprocessor technology used). As an example, consider:

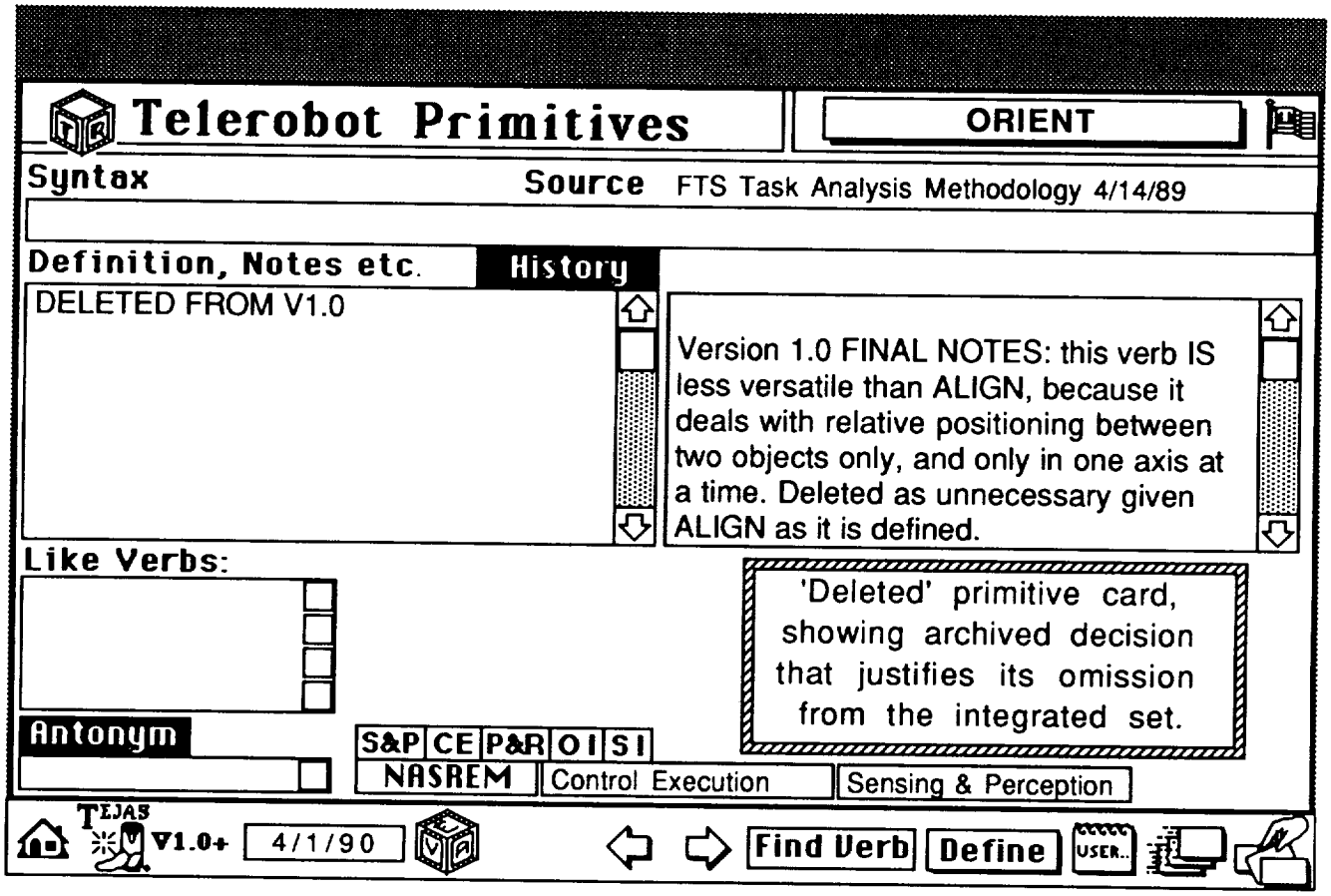
EV1 HANDOFF portable foot restraint to EV2 — *This specific EVA primitive...*

FTS ACQUIRE EV2
FTS LOCATE EV2
FTS MOVE portable foot restraint to EV2
FTS VERIFY EV2 has grasped portable foot restraint
FTS UNGRASP portable foot restraint

...may equate to this set of specific telerobot primitives.

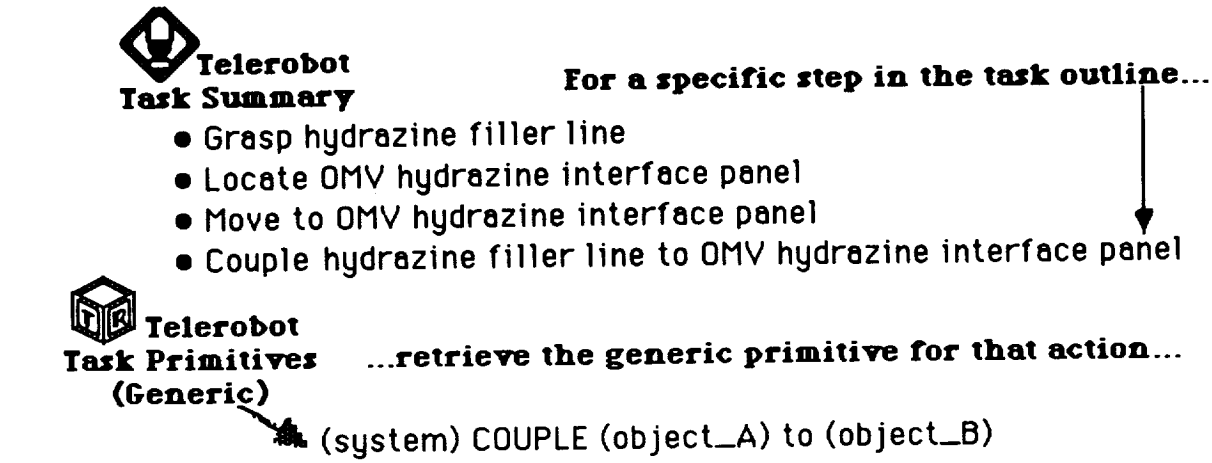
- Relationships between EVA and telerobotics are through specific primitives, not generic primitives. These links are therefore task-dependent.

TEJAS V1.0 | 3/30/90 | Help Menu | Define

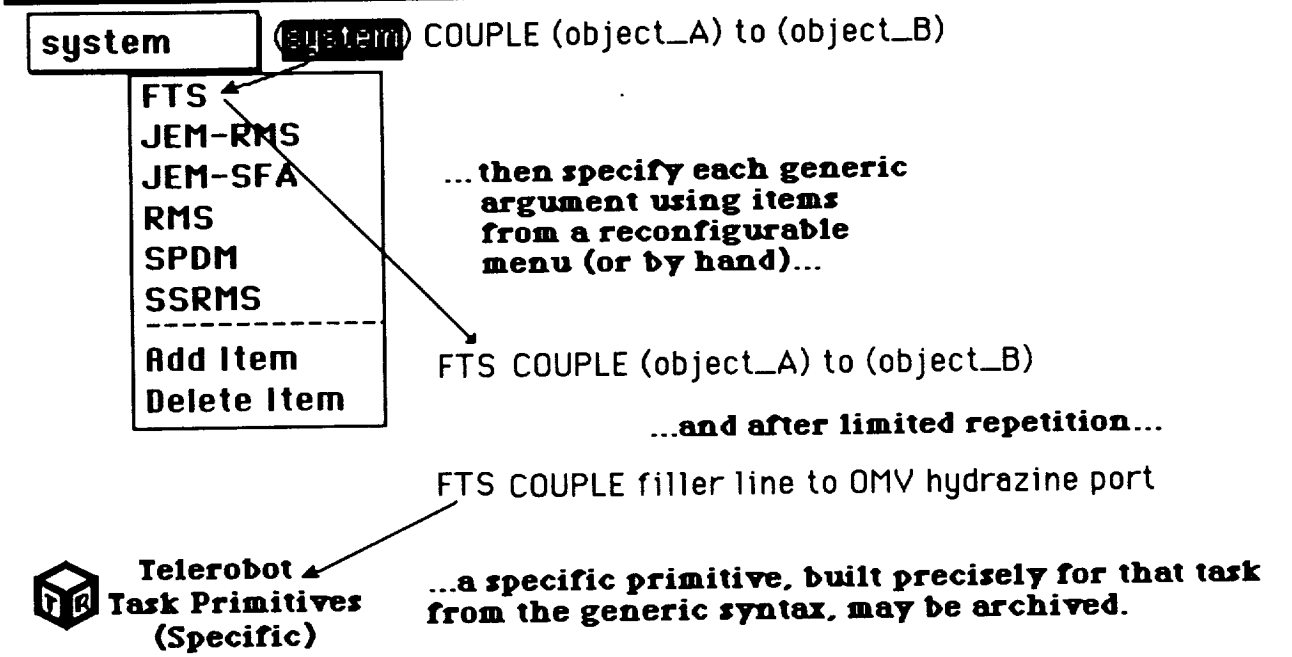


Building Specific From Generic Primitives

Specific primitives are built by specifying the generic arguments of a generic primitive syntax to fit the circumstances of a particular task. The specific primitives list approximates the outline for that task (see "Task Analysis in TEJAS," Help section 8.4.6).



Building Specific From Generic Primitives



TelePrimitives Stack - Card Backgrounds

There are four different backgrounds in this stack. By specific name:

TelePrimitives.bg – main background for this stack. Different cards for each verb primitive. Incorporates primary information fields: ten visible background fields of different types, two hidden scrolling fields.

TelePrimsParsing.bg – specialized, for the Syntax Parsing card only. Unlocked, but a reference for all information cards in the stack. Changes are best made via the User Notes comments field (Help section 6.5).

TelePrimsMenu.bg – specialized, for the Menu Builder Card only. Unlocked, but a reference for all information cards in the stack. Changes are best made via the User Notes comments field (Help section 6.5).

Contributions.bg – specialized, for the Contributions Card only. Unlocked.

TelePrimitives Stack - Information Fields

There are nine information fields common to the 'EVAPrimitives.bg' background: Verb, Def/Notes, Syntax, Like Verbs, Antonym, Source, History, NASREM 1 and NASREM 2. Field specifications are on the following cards.

If at any time, you disagree with the contents of an unlocked field, you may change it. You can change the Definition, generic Syntax, Like Verbs and Antonym if you wish, but remember that the like verbs and antonym form a kind of thesaurus; do not change them without careful consideration.

Leave locked fields and the History field alone. Make general comments in the User Notes hidden field, either as a reminder to yourself or to communicate with the TEJAS Editor.

If you want your changes to be considered for compilation, please follow the simple conventions (e.g., verbs capitalized, generic syntax arguments in parentheses, etc.) detailed in the field specifications cards that follow.

TelePrimitives Stack - Information Fields

Field specifications:

Verb: unlocked, unlabeled shadow field at top right. Contains one- or two-word primitive verb. One-word verbs are desirable; two-word verbs (verb plus adverb or article) are used only to differentiate between different primitives with identical verbs. First word of verb is all capital letters.

Def/Notes: unlocked, labeled scrolling field at middle left. Contains definition and notes about the verb primitive, as compiled from the original definition and changes made during the review process.

Syntax: unlocked, labeled rectangle field across top of card. Contains the suggested generic syntax for the primitive with generic arguments (in parentheses) connected by prepositions (see 'Parsing Scheme Card,' Help section 7.5.14). Both format and content can be changed; submit suggested changes to the TEJAS Editor.

TelePrimitives Stack - Information Fields

Field specifications cont'd:

Like Verbs: unlocked, labeled rectangle field at lower left. Contains list of verbs with similar connotations to the present verb. Like Verbs ARE NOT SYNONYMS! Synonymous verbs would be redundant; however, Like Verbs are distinct, in definition and use (example: INSPECT has like verbs MONITOR, TEST and VERIFY). Pressing on the square button opposite a like verb takes you to that card.

Antonym: unlocked, labeled rectangle field beneath the Like Verbs field. Logically, only one antonym may (and should) exist, since there are no synonyms, only like verbs. Pressing on the square button opposite the verb antonym takes you to that card. If none of the primitive verbs in the stack applies as an antonym, the field will be blank. If there logically is no antonym, the field will say 'none'.

TelePrimitives Stack - Information Fields

Field specifications cont'd:

Source: unlocked, labeled transparent field at upper right. Contains an abbreviated reference to the document or notes where the verb first came to the attention of the TEJAS project. For more definitive titles, see the Contributions Card (last card in the stack).

History: unlocked, labeled, hidden scrolling field at middle right, alongside Def/Notes. Contains "ORIGINAL DEFINITION (from Source):" for the verb primitive, notes, redlines, etc. received (with sender's name or initials) during the review process, and "Version 1.0 FINAL NOTES:" that tell how final definition evolved. Used for traceability; normally not printed. Visibility of this field is set via the History button (see Help section 7.5.12).

TelePrimitives Stack - Information Fields

Field specifications cont'd:

NASREM 1 and NASREM 2: unlocked, labeled rectangle fields to the right of the 'NASREM' button at the bottom of each card. Contain the NASREM areas most closely associated with that verb.

NOTE: This information is experimental; GENERIC task primitives are difficult to classify. Depending on the mode (e.g., teleoperated vs. autonomous), a motion primitive such as MOVE may or may not require Planning & Reasoning, but it is always primarily a Control Execution verb. Therefore, TWO fields are provided for NASREM categorization; their relative weight is equivalent. The purpose of these fields is to provide a key word to help identify the required telelerobotics technologies, which ARE classifiable in a single NASREM area. The best way to check these entries is to USE the telerobot primitives and see if the NASREM categorization is useful and accurate.

EVAPrimitives Stack - Buttons

There are four buttons in the 'EVAPrimitives.bg' background that access information about each verb primitive, or a related one. They are

☐ - the square buttons are used to access Like Verbs and the Antonym for each verb. Click on these to navigate to the verb closest to each button.

History - the History field is hidden, to provide a space on the right side of each card for other information (graphic, video, or other text fields, for instance). Clicking on this button highlights it and shows the field; clicking again hides the field and turns the highlighting off.

Find Verb - to find a particular verb primitive, click here. A dialog box will ask "Find what Verb?". Type it in (capitalization not required) and click OK (or press return). If not found, a message will tell you so. Try again - you may have misspelled it. Using this button is faster than scanning cards one at a time with the Next, Previous, or Show buttons.

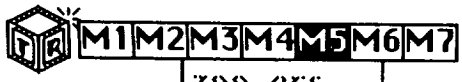
EVAPrimitives Stack - Buttons

- the 'EVAPrimitives block' button at the upper left corner of the EVAPrimitives cards is part of a customized, powerful script that creates a set of selectable menus of the verb primitives for quick navigation. The menus are updateable; they can vary with additions or deletions to the verb list. They are maintained by the 'Menu Builder' card (see Help section 7.4.15). This was a special challenge.

Pop-up menus are limited to 256 characters total. To stay within this limit, the HyperTalk script behind this button takes the total number of characters for all verbs, conservatively divides it by 220, and mathematically finds the starting and ending verbs for the number of M menus required to list all the verbs (averaging 25 verbs per menu). The script then shows that many M buttons (up to seven).

All this happens very quickly, as the first step in using the button. For the second step, go to the next card --->

TelePrimitives Stack - Buttons



Clicking and holding down on any of the M buttons immediately causes a pop-up menu to appear with primitive verbs, starting and ending as specified by the Menu Builder card. Non-selectable verbs are shadowed; they are the deleted (omitted) primitives left in the stack for traceability (use the Find Verb, Show, Next, or Previous buttons to go to them). All other 'boldface' verbs are selectable; pulling the cursor down and releasing on them will take you to that card. Releasing the mouse on a deleted verb or off the menu will cause the menu to disappear. That's all - you won't go anywhere. To hide the M buttons, just click on again.

This process varies in speed with RAM size and processor. With the Mac SE and Plus, it is fairly slow.

NOTE: This is a custom menu system.

Please send comments!

TEJAS V1.0 Help Menu Define USER..

TelePrimitives Stack - Buttons

- a corresponding 'EVAPrimitives block' button is located at the BOTTOM of each primitive card. This button provides a quick way to check for the presence of that same verb in the EVAPrimitives stack. Relatively few verbs are common; the telerobotics 'language' is more precise than the EVA parlance that has evolved in manned spaceflight. Common verbs generally have quite different definitions; these differences can be VERY enlightening (try this button at the teleprimitive ATTACH).

To use this button, click on it. If there IS an exact match, the script will save your place, then take you to that card in EVAPrimitives. You can read it, then return to the teleprimitive by using the T-flag, or pressing 'escape'.

If the script cannot find the EXACT same verb in the other stack, it will answer "No exact match," and leave you in place. That may peak your curiosity to see just what crew-EVA primitive DOES correspond (if any). You can then go to the EVAPrimitives stack and search manually.

TEJAS V1.0 3/30/90 Help Menu Define USER..

Relating EVA and Telerobot Primitives

Telerobot primitives are much less complex than EVA primitives, because humans can multitask (perform more than one function at the same time) to deal with larger chunks of tasks than telerobots can. To see this, compare the syntax parsing schemes for TelePrimitives (Help section 7.5.14) and EVAPrimitives (Help section 7.4.14).

The definition, syntax, and other information must be complete for each telerobot of EVA primitive. The syntaxes of both telerobot and EVA primitives have generic arguments that lead to a virtually infinite set of potential specific primitives.

The transformation from generic primitives (in these stacks) to specific primitives is task-dependent and takes place in the Specific Tasks stacks (e.g., TeleTask.4893, TeleTask.3225, etc.). For each task, a set of specific telerobot primitives must be built to construct a script that follows the task outline (see 'Building Specific from Generic Primitives,' Help section 7.5.9).

Relating EVA and Telerobot Primitives

The relationship between EVA and telerobot primitives is one-to-many. That is, a single EVA primitive usually relates to a set (more than one) of telerobot primitives. TEJAS attempts to build that link in the direction EVA-> Telerobotics, because EVA primitives are better understood than telerobotics primitives (telerobotics is a much younger evolving science).

It is difficult, almost impossible, to create definite links between generic, rather than specific, EVA and telerobot primitives. There are two reasons:

- The selection of a telerobot primitive may be telerobot-dependent. For example, the RMS would RELEASE a payload or object, but a telerobot with a multifingered end effector ('hand') would UNGRASP it.

- The order and selection of telerobot primitives may depend upon the mode of operation – pure teleoperation, automated sequences, traded control, shared control, supervised autonomy, etc.

Relating EVA and Telerobot Primitives

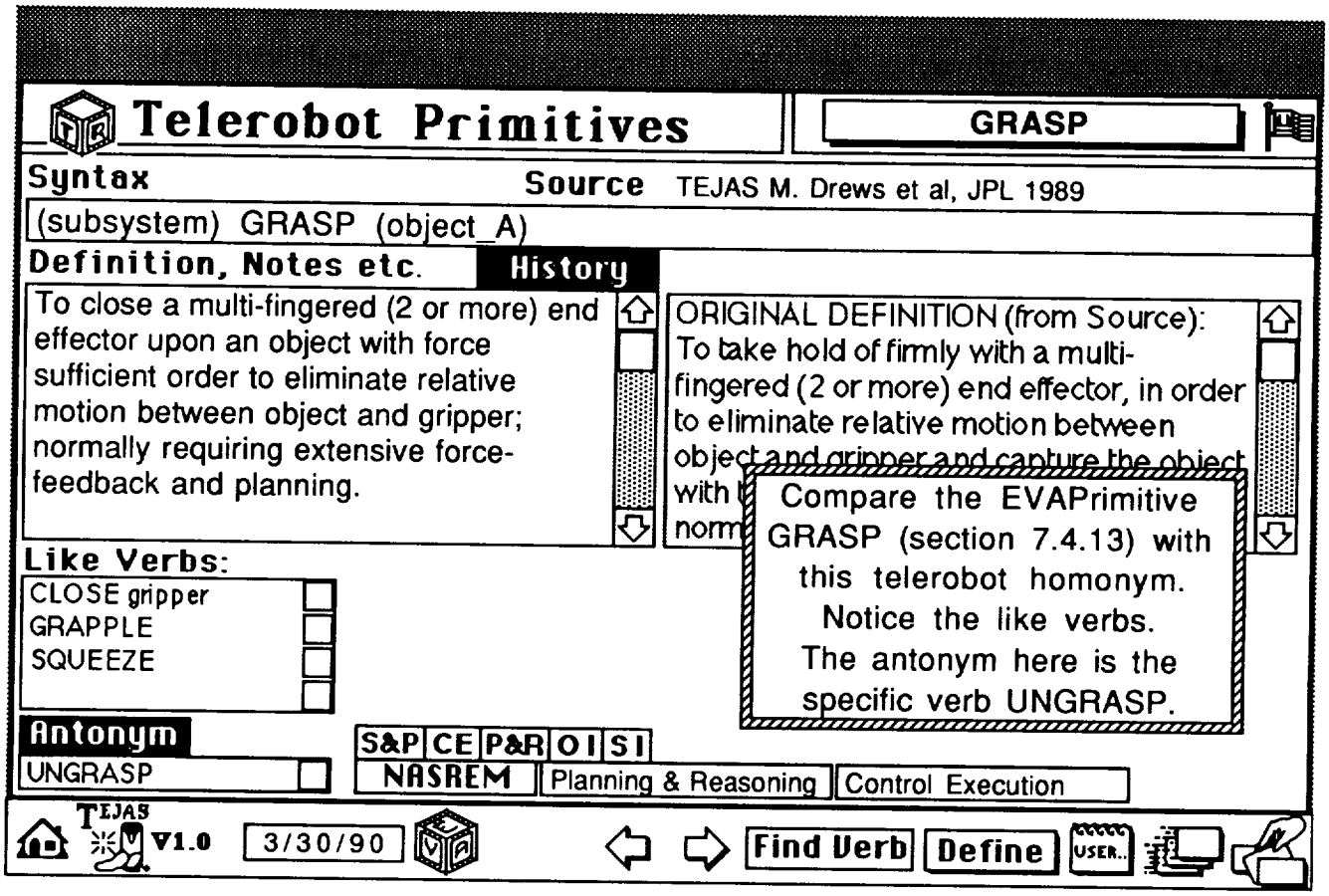
Although generic EVA and telerobot primitives may not be matched in a fixed relationship, there are clearly similarities in definition and syntax between verbs in either list. This is both intentional and desirable.

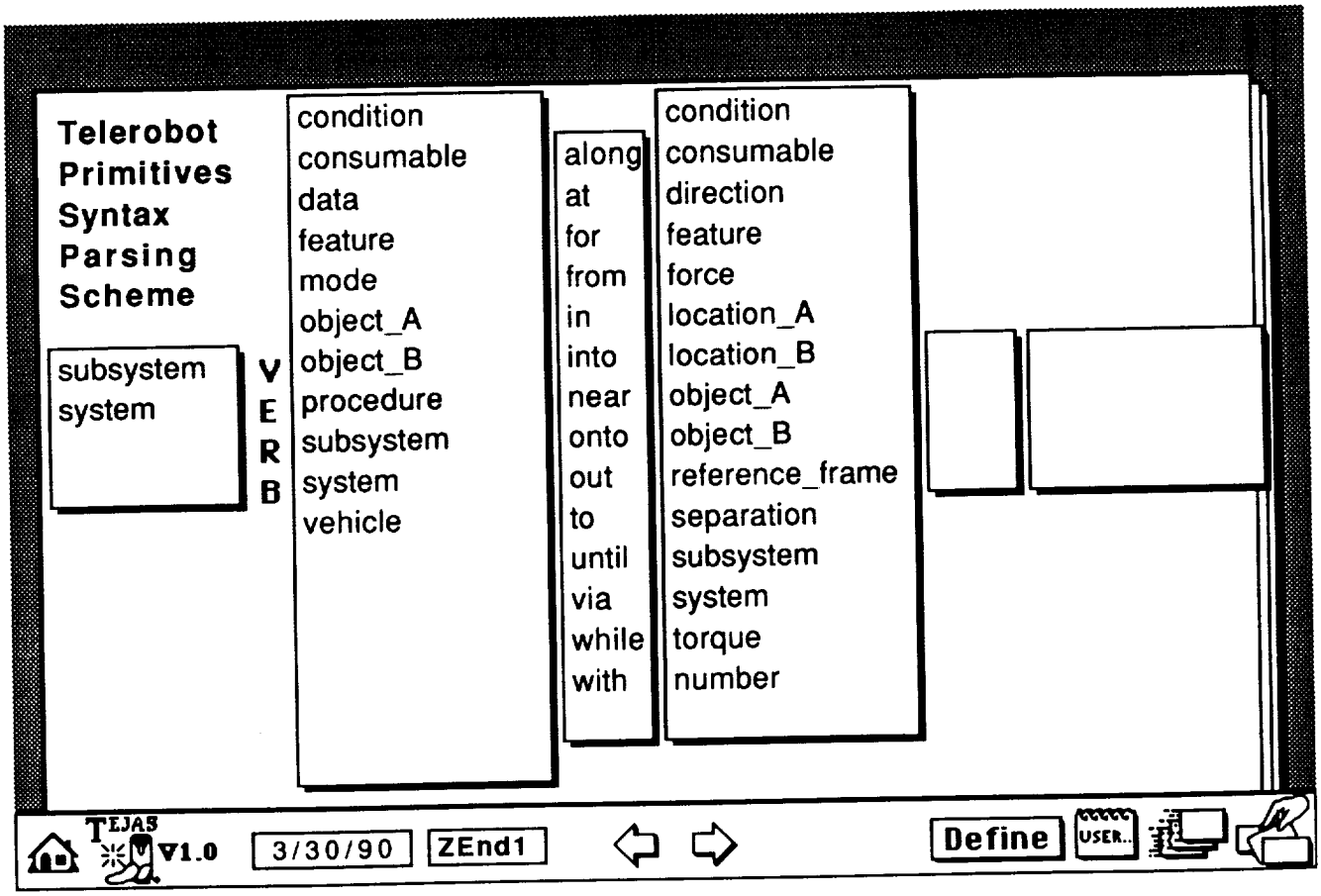
In the TelePrimitives stack, a button has been provided (Help section 7.5.12) to seek the same verb in the complementary EVAPrimitives stack. Sometimes primitives with the same verb but different meanings exist in both stacks (e.g., RELEASE). It can be instructional to see these homonyms.

With a standardized set of generic telerobot and EVA task primitives, a set of relational rules between the specific primitives that evolve from each generic list should be attainable. A researcher will be able to use these sets of rules to trade off using telerobots or EVA crew in a task or subtask.

Much more work needs to be done in this area. The TEJAS primitives stacks are a solid beginning, based on a cooperative effort.

TEJAS V1.0 | 3/30/90 | Help Menu | Define | USER





TelePrimitives Stack - Parsing Scheme Card

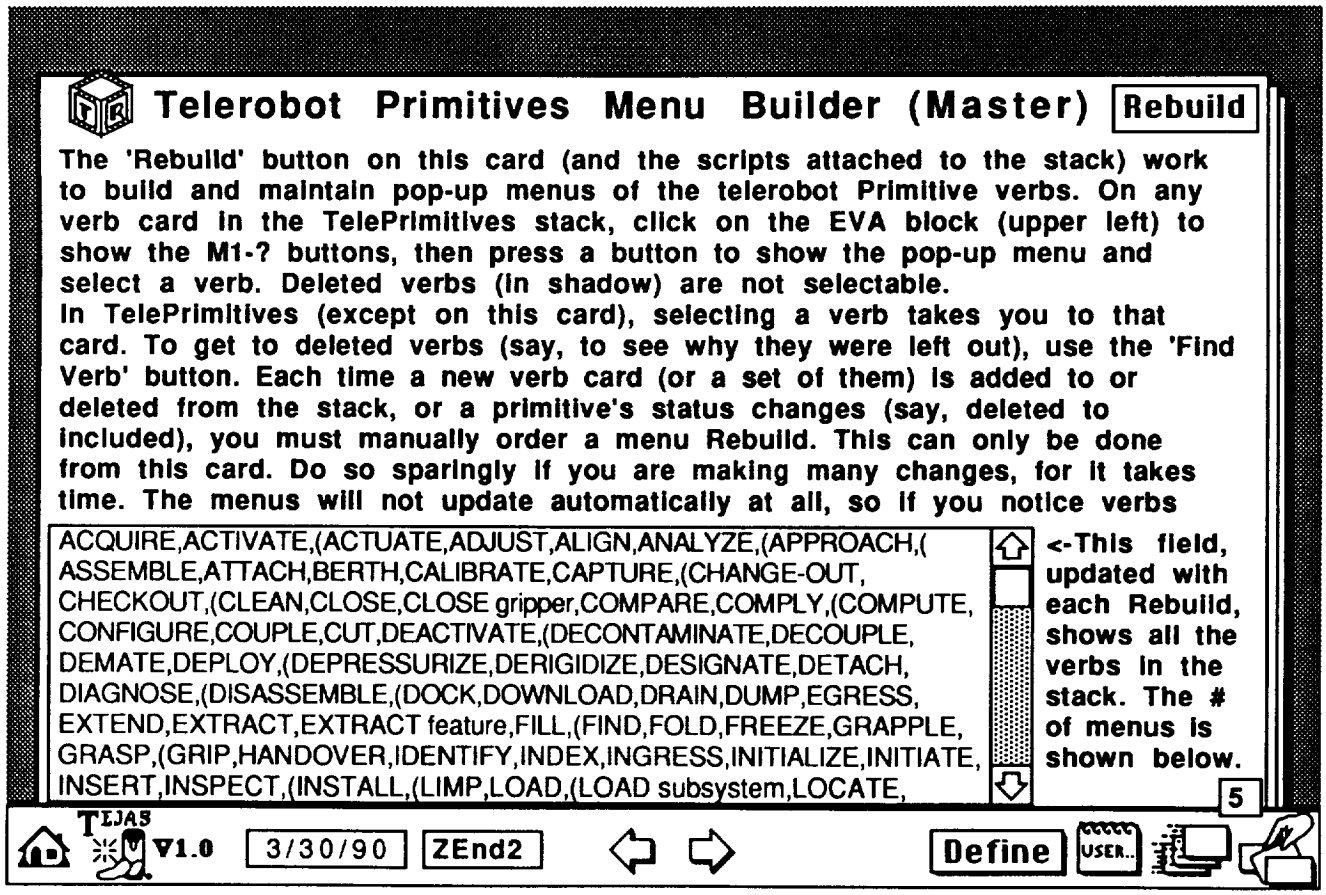
The Parsing Scheme card is found third from the last in the stack. Its sole purpose is to suggest how to build and modify GENERIC syntaxes for task primitives. It is printed in the "TEJAS User's Guide" for use as a guide. The following discussion on syntax is from "Generic Extra-Vehicular Activity (EVA) and Telerobot Task Primitives for Analysis, Design, and Integration, Version 1.0: Reference Compilation," JPL Publication 90-10. To read it, scroll down on the field below.

The syntax used in both the crew-EVA and telerobot generic primitives is important, to ensure that information needed to perform analyses on the finished specific primitives will be present in them. Let's take an example:

(subsystem) ALIGN (object_A) [with (object_B/reference_frame)]

This telerobot primitive shows the generic 'subject VERB predicate' syntax used with all primitives in both the EVA and telerobot primitives lists. The subject is always a noun; in the case of a telerobot, either (system) (i.e. the RMS, SPDM, or FTS) or

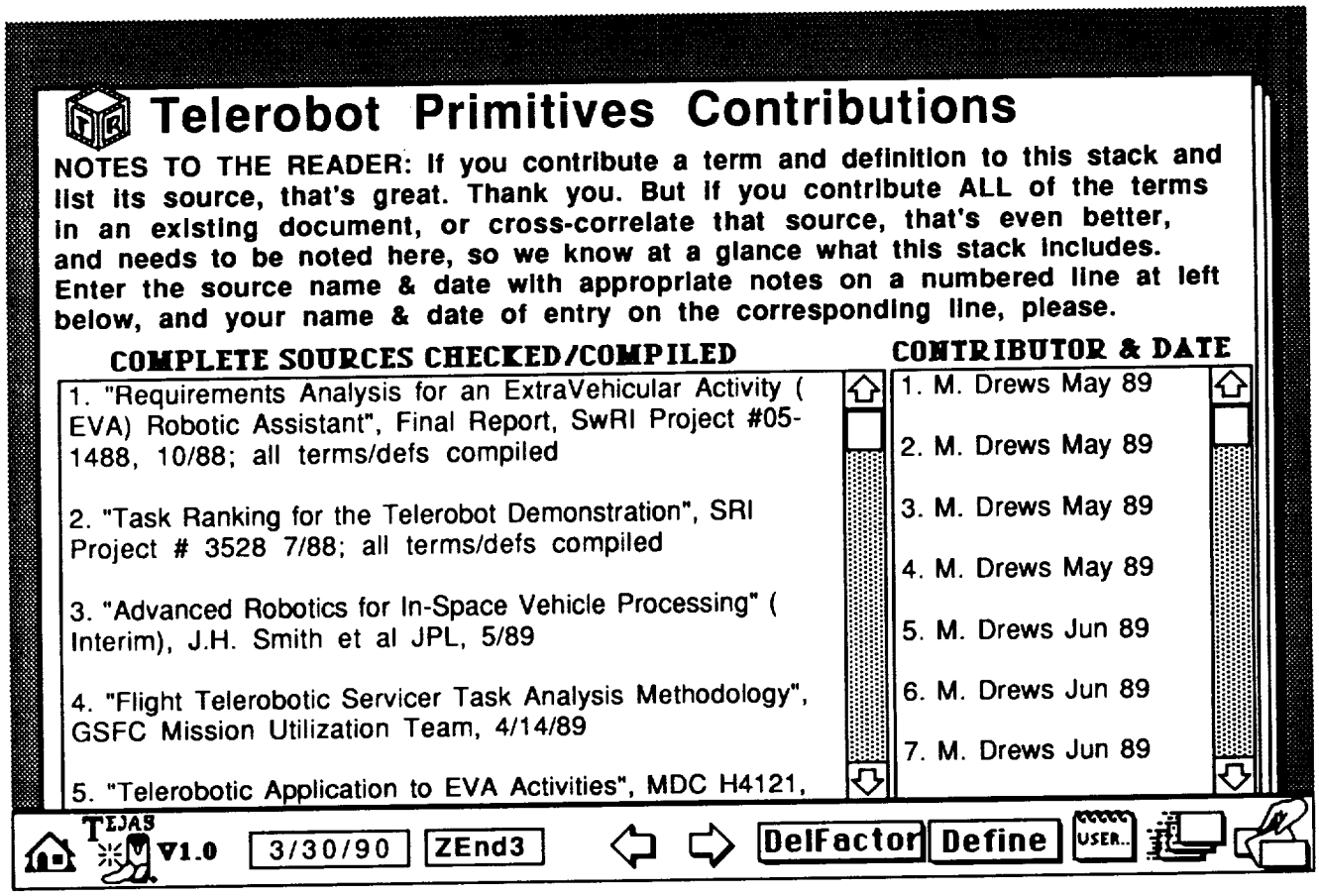
TEJAS V1.0 3/30/90 Help Menu Define USER..



TelePrimitives Stack - Menu Builder Card

The Menu Builder card, second from the last in the stack, maintains the pop-up menus of primitive verbs available from the 'TelePrimitives block' buttons (Help section 7.5.12). This card's visible and hidden fields and scripts work to rebuild and store these verb menus. The scripts' notation ensures that deleted verbs are non-selectable. The text on the card explains how to use it; be aware that rebuilding takes some time (longer for low-RAM Macs). Rebuild only when you have made a group of changes.

The selectable menus that this card and the scripts attached to the Primitives block and M buttons give you are more than a convenience. They provide the only place to view all the primitives in a complete list, noting which were included in the Version 1.0 integrated list and which were deleted (omitted). Viewing the list takes far less time than viewing cards one at a time or using the Show button. This facility cannot be built into other reference stacks (such as TeleTechnologies) because the number of characters in the different items makes menus impractical.



TelePrimitives Stack - Contributions Card

The LAST card of every reference stack is like this one. When compiled, these cards form a bibliography of the TEJAS effort. The 'References' scrolling field gives a detailed list of documents, notes, or other sources that are also identified by abbreviations in the Source fields on the stack's information cards. Each reference also contains a short note about how the source was used. The corresponding numbered lines in the 'Contributor' scrolling field list who contributed the information and when. This data contributes to the TEJAS goal of "total traceability."

With the primitives stacks, this card is particularly important. As the primitives are used, modified, and used again, this card will not be wiped clean. Instead, it will show, by the number and date of entry, the progression of compilation of community knowledge into a universal primitives stack. Please read and follow the card's instructions. If there is a reference that you think should be added but that you will not be compiling, let the TEJAS Editor know.

SECTION VII

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APPENDIX A

GLOSSARY

Crew-EVA	EVA performed specifically by crew
EV1 or EV2	Terminology in EVA planning to denote crewmember 1 or 2
EVA	Extravehicular activity (work performed outside the spacecraft)
FTS	Flight Telerobotic Servicer
generic crew-EVA primitive	A primitive activity to be performed by crew
generic primitives	The primitive activities used to perform work (crew or telerobot)
generic telerobot primitive	A primitive activity to be performed by a telerobot
IVA	Intravehicular activity (work performed inside the spacecraft)
JPL	Jet Propulsion Laboratory
JSC	Johnson Space Center
KSC	Kennedy Space Center
LaRC	Langley Research Center
MDSSC	McDonnell-Douglas Space Systems Company
MMU	Manned Maneuvering Unit
NASA	National Aeronautics and Space Administration
ORU	Orbital Replaceable Unit
P&RS	Planning and Reasoning Subsystem
RMS	Remote Manipulator system
SPDM	Special Purpose Dextrous Manipulator
specific primitives	The invocation of a generic primitive to perform a specific activity as defined by its arguments

SSF	Space Station *Freedom*
SSLVLH	Space Station Local Vertical Local Horizontal
SSRMS	Space Station Remote Manipulator System
TEJAS	Telerobotics/EVA Joint Analysis System

APPENDIX B

GENERIC CREW-EVA PRIMITIVES HISTORY

Verb: ACTIVATE
Source: "Telerobotic Application to EVA" MDAC 10/88
History: ORIGINAL DEFINITION (from Source):
To initiate system operation, including power up and initialization.

JPL: no comment

KLAUS: no comment

REAUX: no comment

HENEGHAN: no comment

Version 1.0 FINAL NOTES: accepted as originally defined.

Verb: ADJUST
Source: Adv. Robotics for Veh. Proc. (Interim) JPL 5/89
History: ORIGINAL DEFINITION (from Source):
To alter or change the appearance of an object in order to accommodate (e.g., ADJUST foot restraint for proper positioning).
(crew) ADJUST (object A)

KLAUS: delete

REAUX: delete

Version 1.0 FINAL NOTES: agreed; ideas incorporated into other ADJUST.

Verb: ADJUST
Source: "Telerobotic Application to EVA" MDAC 10/88
History: ORIGINAL DEFINITION (from Source):
To change the location or setting of an object (syn: reorient)

JPL: drop synonym as redundant; reconcile with other ADJUST.

KLAUS: change 'location' to 'orientation'

REAUX: Change definition to: 'To change setting of an object.' If you're changing the location, that fits the description of align.
Change definition to: 'To change the location or setting of an object .'

Version 1.0 FINAL NOTES: definition altered as suggested by comments received. Helps to make the distinction between this ADJUST, and ALIGN.

Verb: ALIGN
Source: "Telerobotic Application to EVA" MDAC 10/88
History: ORIGINAL DEFINITION (from Source):
To position an object with respect to another object or reference frame.

KLAUS: no changes
(position, configure, route)

REAUX: no comment

Version 1.0 FINAL NOTES: definition changed slightly for clarity.

Verb: ASSEMBLE
Source: D. Klaus JSC comts on "T/R & EVA Task Anal"
History: ORIGINAL DEFINITION (from Source):
To fit or put together parts (syn: construct).

SUGGESTED ADDITION. KEEP AS IS, CHANGE, OR LEAVE OUT.

MLD: probably required, but definition needs to be a little more precise.

HENEGHAN: delete, too high-level.

Version 1.0 FINAL NOTES: used in limited, specific instances as defined, this can be a primitive and needs to be included.

Verb: ATTACH
Source: D. Klaus JSC comts on "T/R & EVA Task Anal"
History: ORIGINAL DEFINITION (from Source):
To fasten, join, or connect.

SUGGESTED ADDITION. KEEP AS IS, CHANGE, OR LEAVE OUT.

MLD: make more precise, re: the corresponding TelePrimitive.

HENEGHAN: delete in favor of MATE with a more detailed definition.

MLD: suggest we keep it, with a definition something like that shown at right. Reason: how do you deal with NONcomplementary connectors? One doen't MATE a snap swivel on the end of the tether reel to a slidewire.

Version 1.0 FINAL NOTES: definition is covered by INSTALL, MATE and SECURE.

Verb: BERTH
Source: D. Klaus JSC comts on "T/R & EVA Task Anal"
History: ORIGINAL DEFINITION (from Source):
none
SUGGESTED ADDITION. DEFINE OR LEAVE OUT.
(crew) BERTH (object A)

MLD: if this is kept as a verb to use with spacecraft, it is highly unlikely (except as a contingency, as with the Palapa B2/Westar recovery) that an EVA-suited crewperson will do it. Recommend deletion for that reason, and because it is not a primitive by the established definition.

HENEGHAN: delete, too high-level.

Version 1.0 FINAL NOTES: deleted for the aforementioned reasons. If a workstation were provided to the EVA crewperson to operate a mechanical BERTHing device from outside its spacecraft, then just as with the IVA crew, that EVA crewperson would become part of the telerobot system, and hence the verb would still be a telerobotic primitive.

Verb: BOLT
Source: D. Klaus JSC comts on "T/R & EVA Task Anal"
History: ORIGINAL DEFINITION (from Source):
none
SUGGESTED ADDITION. DEFINE OR LEAVE OUT.
(crew) BOLT (object A) with (tool)

MLD: probably needed; make more precise, re: the corresponding TelePrimitive.

HENEGHAN: delete. The actions involved in BOLTing can be described through other primitives, such as: GRASP, MATE, ROTATE, SECURE. in an effort to keep the primitive list at a reasonable length, BOLT should not be added.

MLD: true, but don't need to tell crew that. Remember, these primitives are for people to describe discrete actions another person (albeit in a spacesuit) must take; they wouldn't go to that level of detail unless the procedure were completely unfamiliar (see note under STOW). Think the central issue is whether to call out this particular type of attachment primitive vs. saying INSTALL bolt or FASTEN bolt, etc. See note under LATCH. Standard crew checklist for use with tools would solve the question.

HENEGHAN: a more elaborate definition for SECURE satisfies the above requirements.

Version 1.0 FINAL NOTES: deleted with the suggested changes to REMOVE.

Verb: CHECKOUT
Source: D. Klaus JSC comts on "T/R & EVA Task Anal"
History: ORIGINAL DEFINITION (from Source):
To examine or investigate a situation or object.

SUGGESTED ADDITION. KEEP AS IS, CHANGE, OR LEAVE OUT.

MLD: I think this has come to mean more to initiate a preprogrammed evaluation sequence (e.g. 'perform checkout'). Do we need it? Look at the other related terms.

HENEGHAN: do not add; covered by other verbs (i.e., TEST, INSPECT, VERIFY).

Version 1.0 FINAL NOTES: rejected for the above reasons.

Verb: CLEAN
Source: "Telerobotic Application to EVA" MDAC 10/88
History: ORIGINAL DEFINITION (from Source):
To clean off a contaminated surface of an object (syn: decontaminate).

JPL: Replace with 'To remove unwanted contaminants, impurities, or objects from a surface, using an active agent (e.g a fluid, brush, etc.).' NOTE: Never use verb in definition.

KLAUS: Delete 'To clean off a contaminated surface of an object'
'Delete 'PROPOSED: Replace with'
Delete 'NOTE: Never use verb in definition.

REAUX: no comment.

Version 1.0 FINAL NOTES: accepted as defined.

Verb: CLOSE
Source: Adv. Robotics for Veh. Proc. (Interim) JPL 5/89
History: ORIGINAL DEFINITION (from Source):
To put an object (e.g., a door, valve or hatch) in a position so as to obstruct an opening, entrance etc.

ESTUS: include 'conduit' in the definition.

KLAUS: change definition to 'To shut off or obstruct an opening.'

REAUX: no comment.

Version 1.0 FINAL NOTES: definition expanded to contain suggested changes.

Verb: CLOSEOUT
Source: Adv. Robotics for Veh. Proc. (Interim) JPL 5/89
History: ORIGINAL DEFINITION (from Source):
To terminate the operation of a (sub)system, stow gear, inspect and, if necessary, connect power cables and recharge.
(crew) CLOSE DOWN (system)

KLAUS: Change title to 'Terminate' change definition to read, 'Don't define a primitive with another primitive!'

REAUX: no comment

JPL: delete in favor of SHUTDOWN.

Version 1.0 FINAL NOTES: delete as compound and covered by existing primitives.

Verb: COLLECT
Source: "Telerobotic Application to EVA" MDAC 10/88
History: ORIGINAL DEFINITION (from Source):
To gather objects together.
(crew) COLLECT (objects)

JPL: Requires better definition; too ambiguous to be useful at this time. Comments, please.

KLAUS: Change 'COLLECT' to 'OBTAIN'
Delete definition

REAUX: Not really a task primitive, at least by this definition.

HENEGHAN: delete, covered by other primitives.

Version 1.0 FINAL NOTES: deleted as redundant to other primitives.

Verb: COMMUNICATE
Source: "Telerobotic Application to EVA" MDAC 10/88
History: ORIGINAL DEFINITION (from Source):
To interchange information with another person

JPL: Replace 'interchange' with 'exchange'

KLAUS: change definition to read, 'To give and/or receive info, signals or messages.'

(crew) COMMUNICATE (information) 'to [recipient]

REAUX: This may be appropriate also as an EVA crew primitive.

HENEGHAN: it is very difficult to assign times to COMMUNICATing since it is usually an ongoing process. Definition should include exchanges with (sub)system. Include 'with (crew/subsystem)' in the syntax.

Version 1.0 FINAL NOTES: OK with few changes.

Verb: CONFIGURE
Source: Adv. Robotics for Veh. Proc. (Interim) JPL 5/89
History: ORIGINAL DEFINITION (from Source):
To arrange an object for a specific purpose (e.g., to arrange tools on a toolboard).

KLAUS: Change definition to 'To arrange an object or objects in a specific manner.' (e.g., to arrange tools on a toolboard).
(may be specified by a combination of other primitives)

JPL: add '[object B]' to the syntax.

REAUX: no comment.

Version 1.0 FINAL NOTES: standard EVA parlance; accepted with few changes as shown.

Verb: CONNECT
Source: "Telerobotic Application to EVA" MDAC 10/88
History: ORIGINAL DEFINITION (from Source):
To link two objects together (syn: mate)
(crew) CONNECT (object A) to (object B)

KLAUS: Change definition to: 'To join or fasten' two objects together. (syn: mate)

REAUX: no comment.

JPL: delete in favor of MATE.

Version 1.0 FINAL NOTES: deleted as redundant to the more precise MATE, which implies complementary connectors.

Verb: CONSTRUCT
Source: D. Klaus JSC comts on "T/R & EVA Task Anal"
History: ORIGINAL DEFINITION (from Source):
To put together systematically (syn: assemble)

SUGGESTED ADDITION. KEEP AS IS, CHANGE, OR LEAVE OUT.

MLD: this has been used in the past in EVA, especially with trusses. There is a difference with ASSEMBLE in that the dictionary does specify 'systematically', as Dave did. Recommend keeping, but dropping the synonym; put it instead into the related terms field.

HENEGHAN: do not add. This is too high-level to be a primitive.

Version 1.0 FINAL NOTES: delete in favor of ASSEMBLE, used in limited, specific instances.

Verb: COORDINATE
Source: R. Reaux CTA Inc, comts on "T/R & EVA Task Anal"
History: ORIGINAL DEFINITION (from Source):
To synchronize one's actions with another's.

SUGGESTED ADDITION. KEEP AS IS, CHANGE, OR LEAVE OUT.

HENEGHAN: do not add. This can be described by the specific verbs for the actions and the verb COMMUNICATE.

Version 1.0 FINAL NOTES: rejected as unnecessary.

Verb: COVER
Source: Adv. Robotics for Veh. Proc. (Interim) JPL 5/89
History: ORIGINAL DEFINITION (from Source):
To place a protection (e.g., micrometeor shield, MLI) over or upon object A, and fasten in place; condition: hard, soft.
(crew) (condition) COVER (object A) with (object B)

JPL: change definition to 'To place a barrier (e.g., micrometeor shield, MLI) over or upon an object to protect the object from environmental hazards, and fasten in place; condition (describes the cover): hard, flexible.'

KLAUS: 'change COVER to INSTALL? needs details; "cover" is not appropriate'.
Delete definition.

REAUX: EVA hard COVER attached payload isn't really appropriate. (crew) COVER (object A) [with object B].

HENEGHAN: use (covering) in the syntax.

MLD: think this primitive should be deleted for the same reasons as LATCH, BOLT, etc. Namely that it is covered (no pun intended) by the proper definition for INSTALL.

Version 1.0 FINAL NOTES: deleted with the suggested changes to INSTALL.

Verb: DEACTIVATE

Source: "Telerobotic Application to EVA" MDAC 10/88

History: ORIGINAL DEFINITION (from Source):
To terminate system operation. Includes system shut down sequence and power shut off.
(crew) DEACTIVATE (system)

JPL: Delete in favor of SHUTDOWN. This is not general EVA parlance; rather, it pertains to telerobotics.

KLAUS: delete

REAUX: To terminate system operation. Includes system shut down sequence and power shut off.

Version 1.0 FINAL NOTES: delete in favor of SHUTDOWN.

Verb: DECONTAMINATE

Source: Adv. Robotics for Veh. Proc. (Interim) JPL 5/89

History: ORIGINAL DEFINITION (from Source):
To remove or neutralize any undesirable substances adhering to the outside surfaces of an object (e.g., outgas from the EEU).
(crew) DECONTAMINATE (object A)

JPL: delete in favor of CLEAN.

KLAUS: change DECONTAMINATE to 'CLEAN' delete definition

REAUX: no comment.

Version 1.0 FINAL NOTES: deleted in favor of CLEAN.

Verb: DEMATE
Source: Adv. Robotics for Veh. Proc. (Interim) JPL 5/89
History: ORIGINAL DEFINITION (from Source):
To take apart or disconnect joined parts (object A from object B), e.g., detach Velcro interface, unplug power umbilical; condition 1: The type of connection or mating (e.g., quick connect, captive pin, threaded interface, etc.)
condition 2: one-handed, two-handed.

JPL: change to: 'To take apart or separate joined parts (object A from object B), e.g., detach Velcro interface, unplug power umbilical; condition 1: The type of connection or mating (e.g., quick connect, captive pin, threaded interface, etc.) (syn., disconnect)' condition 2 is not needed.

KLAUS: syn. detach, unlatch, disconnect

REAUX: no comments

Version 1.0 FINAL NOTES: definition changed as suggested; tries to accommodate demating different types of complementary mechanical interfaces.

Verb: DEPLOY
Source: "Telerobotic Application to EVA" MDAC 10/88
History: ORIGINAL DEFINITION (from Source):
To set-up a system into an operating configuration

JPL: Replace with the following definition: 'To move a mechanical appendage (e.g. a manipulator, an antenna boom, etc.) into its operational configuration. Also, to release a payload (platform or spacecraft) from its carrier spacecraft, using a manipulator or automated mechanical device.'

With RMS operations, CAPTURE and RELEASE are antonyms. DEPLOYing payloads further has been used to mean separating them from a carrier spacecraft into a free-flying state, either in their proper orbit or in a temporary orbit for later insertion into a transfer orbit by means of a mated stage (such as an IUS, or the OMV).
This is another tough one, especially for its multiple meanings and common misusage. Needs discussion. All comments are useful - make them.

KLAUS: Change definition to: 'To unfold or drive (manually or auto) a system into an operating configuration.
Comment after sentence 'With RMS operations ... 'If you said - Deploy radiator - would it be set up or thrown overboard?'

REAUX: Deploy, in the case of relearning a payload is not really a task primitive, and

therefore may not pose a problem. I would suggest retaining to mean deploying mechanical appendage.

HENEGHAN: delete. this seems to be too high-level for this verb list.

Version 1.0 FINAL NOTES: kept with revisions suggested by Klaus/Reaux. Deleted 'vehicle' from the original syntax.

Verb: DETACH
Source: D. Klaus JSC comts on "T/R & EVA Task Anal"
History: ORIGINAL DEFINITION (from Source):
To unfasten or remove, separate.

SUGGESTED ADDITION. KEEP AS IS, CHANGE, OR LEAVE OUT

MLD: probably needed; make more precise, re: the corresponding TelePrimitive.

HENEGHAN: do not add. definition covered by DEMATE.

Version 1.0 FINAL NOTES: deleted because definition is covered by REMOVE.

Verb: DISCONNECT
Source: "Telerobotic Application to EVA" MDAC 10/88
History: ORIGINAL DEFINITION (from Source):
To un-link two objects (syn: demate)
(crew) DISCONNECT (object A) from (object B)

JPL: Replace 'un-link with 'take apart'.

KLAUS: Change definition to 'To break a connection between 2 objects (syn: detach)'

REAUX: This definition is not distinguishable from DEMATE. I suggest revising Demate to mean separate two flexible parts designed to fit together.

HENEGHAN: delete in favor of DEMATE.

Version 1.0 FINAL NOTES: deleted as redundant to the more precise DEMATE, which implies complementary connectors.

Verb: DRIVE
Source:
History:

Verb: EGRESS
Source: Adv. Robotics for Veh. Proc. (Interim) JPL 5/89
History: ORIGINAL DEFINITION (from Source):
To go out of or exit an object, e.g., a foot restraint or airlock.

NOTE: Refers to both leaving a pressurizable volume and leaving a fixture. There is a profound fundamental difference.

KLAUS: Change definition to, 'To go out of or exit a restraining or confining object e.g., a foot restraint or airlock.'

NOTE: Refers to both leaving a pressurizable volume and leaving a fixture. There is a profound fundamental difference.[not really]

REAUX: no comment

JPL: change to: 'To go out of or exit an enclosure for all or part of the body, e.g., a foot restraint or airlock.

Version 1.0 FINAL NOTES: changes made to clarify definition.

Verb: ERECT
Source: D. Klaus JSC comts on "T/R & EVA Task Anal"
History: ORIGINAL DEFINITION (from Source):
To set up (syn: construct, assemble).

SUGGESTED ADDITION. KEEP AS IS, CHANGE, OR LEAVE OUT.

MLD: Recommend deletion. R. H. Dictionary has it as "to construct or fit together by putting materials together; to raise and set in an upright position". This implies either a redundancy with CONSTRUCT, or an implied gravity vector, which on-orbit EVA does not have.

HENEGHAN: do not add. too high-level to be a primitive.

Version 1.0 FINAL NOTES: rejected for the above reasons.

Verb: GRAPPLE
Source: "Telerobotic Application to EVA" MDAC 10/88
History: ORIGINAL DEFINITION (from Source):
To grasp an object either manually or by mechanical means; to secure a hold upon an object with the intention of manipulation. (syn: capture, secure, hold)
(crew) GRAPPLE (object) with (subsystem)

JPL: drop synonyms. Drop 'with the intention of manipulation' as unnecessary.

HENEGHAN: add 'with (subsystem)' to the syntax.

KLAUS: 'GRAPPLE not a human action verb' Change definition to: 'To grasp hold of an object either manually or by mechanical means; use to secure a hold upon an object with the intent of manipulation. (syn: capture, secure, hold)
(hold)

REAUX: Leave Grapple for telerobotic, use Grasp for EVA.

HENEGHAN: GRAPPLE is replaced by GRASP.

Version 1.0 FINAL NOTES: GRAPPLE remains for the exclusive use of enveloping snare-type end effectors normally operated through IVA. If a workstation were provided to the EVA crewperson to operate such a device from outside its spacecraft, then just as with the IVA crew, that EVA crewperson would become part of the telerobot system, and hence the verb would still be a telerobotic primitive.

Verb: GRASP

Source: "Telerobotic Application to EVA" MDAC 10/88

History: ORIGINAL DEFINITION (from Source):
To grlp an object either manually or by mechanical means; to secure a hold upon an object with the intention of manipulation. (syn: capture, secure, hold)

JPL: drop synonyms. drop 'with the intention of manipulation' as unnecessary.

HENEGHAN: add 'with (subsystem)' to the syntax.

KLAUS: 'GRAPPLE not a human action verb' Change definition to: 'To grasp hold of an object either manually or by mechanical means; use to secure a hold upon an object with the intent of manipulation. (syn: capture, secure, hold)
(hold)

REAUX: Leave Grapple for telerobotic, use Grasp for EVA.
Change definition to: 'To grasp hold of an object by mechanical means; use to secure a hold upon an object with the intent of manipulation. (syn: capture, secure, hold) ok

HENEGHAN: GRASP, as the overwhelming favorite, replaces GRAPPLE.

Version 1.0 FINAL NOTES: 'with (subsystem)' is dropped, and 'with (tool)' is made optional in the syntax, since GRASP by the agreed-upon definition is a purely manual activity, but one which may have a tool employed. GRASP does also perform as a telerobotic activity, but with a different defiinition. It should not be difficult to

differentiate between the two in the context of the task for tasks with both EVA and telerobot participants.

Verb: GUIDE
Source: "Telerobotic Application to EVA" MDAC 10/88
History: ORIGINAL DEFINITION (from Source):
To manipulate an object along a desired path to a target destination.
(crew) GUIDE (object) along (path) toward (location)

JPL: Add 'or constraining object (e.g., a slidewire)' after 'desired path'. This is constrained motion from the EVA perspective. Needs better definition. Comments, please.

KLAUS: Change definition to: To direct a course or motion by physical action. (syn: maneuver or transport) (I don't feel that "guide" implies providing means of motion)

REAUX: Change definition to: 'To manipulate an object along a physically designated path to a target destination.'

HENEGHAN: delete. this can be covered by TRANSPORT.

Version 1.0 FINAL NOTES: agreed; deleted as redundant to MANEUVER, PUSH, or PULL when specified along a constraining path or object.

Verb: HANDLE
Source: Adv. Robotics for Veh. Proc. (Interim) JPL 5/89
History: ORIGINAL DEFINITION (from Source):
To manually manipulate (e.g., fold, coil, bunch) flexible material. Object A is defined to be a flexible material (e.g., hose, cable, multi-layered insulation (MLI)).
(crew) HANDLE (object A)

JPL: This is imprecise, and compound to different types of manipulation of flexible materials. Recommend breaking up into FOLD, BUNCH, and ROLL, but the community needs to comment first.

KLAUS: Change definition to: To manually manipulate an object (Object A may be defined to be a flexible material (e.g., hose, cable, multi-layered insulation (MLI)).

REAUX: That's ok for flexible material. But shouldn't handle include other objects?

HENEGHAN: change HANDLE to MANIPULATE, and include other than flexible materials to the definition.

Version 1.0 FINAL NOTES: deleted as covered by MANEUVER, STOW, UNSTOW, etc. Manipulation of flexible objects is for a purpose, and the primitives already exist to

cover each of these. Manual manipulation is not like telerobotics; the same system is used in each case (suited crew). There should be no need for a separate primitive to cover this activity if flexible objects are included as possible specific arguments to the other generic manipulation primitives.

Verb: HANDOFF
Source: M. Drews JPL comts on "T/R & EVA Task Anal"
History: ORIGINAL DEFINITION (from Source):
To give an object to another EVA crewperson or telerobotics work system, relinquishing control of and responsibility for that object to the other system.

HENEGHAN: add 'to the other crewperson or system'. change syntax to (crew/system).

Version 1.0 FINAL NOTES: incorporated as defined, with minor changes.

Verb: HOLD
Source: D. Klaus JSC comts on "T/R & EVA Task Anal"
History: ORIGINAL DEFINITION (from Source):
To restrain or control.

SUGGESTED ADDITION. KEEP AS IS, CHANGE, OR LEAVE OUT.

MLD: Say what? Probably needed, probably used already and ergo, sanctioned. But the definition can be expanded to better understanding. Check dictionary; several good interpretations there. Reconcile with suggested verb RESTRAIN.

HENEGHAN: use RESTRAIN instead.

Version 1.0 FINAL NOTES: disagree with Heneghan; an object can be restrained using the primitive SECURE, but manually retaining a grasp on an object during the performance of a task calls for HOLD. That will be the primitive in this Version.

Verb: IMPLEMENT
Source: "Telerobotic Application to EVA" MDAC 10/88
History: ORIGINAL DEFINITION (from Source):
To follow a plan or a schedule of procedures
(crew) IMPLEMENT (plan)

PROPOSED: Delete as inappropriate terminology for EVA.

KLAUS: Too high-level a verb

REAUX: Delete

HENEGHAN: delete

Version 1.0 FINAL NOTES: deleted as ambiguous.

Verb: INGRESS
Source: Adv. Robotics for Veh. Proc. (Interim) JPL 5/89
History: ORIGINAL DEFINITION (from Source):
To go in or enter, e.g., a foot restraint or airlock.

NOTE: Refers to both leaving a pressurizable volume and leaving a fixture. There is a profound fundamental difference.

JPL: change to 'To insert all or part of the body into an enclosure or holding device, e.g., a foot restraint or airlock.'

KLAUS: Change definition to: To go in or enter a restraining or confining object, e.g., a foot restraint or airlock.
NOTE: Refers to both leaving a pressurizable volume and leaving a fixture. There is a profound fundamental difference.[NO]

REAUX: no comment

Version 1.0 FINAL NOTES: changes made to clarify definition.

Verb: INPUT
Source: R. Reaux CTA Inc. comts on "T/R & EVA Task Anal"
History: ORIGINAL DEFINITION (from Source):
To enter information into a system or database.
(crew) INPUT (information) into (destination)

HENEGHAN: delete, this is covered by COMMUNICATE.

Version 1.0 FINAL NOTES: the last comment above would be correct if the only type of inputs were oral (speech). For the present, this is the only conscious data inputting that EVA crew do, which is not to say that another input system might not be provided, for example at a remote workstation. But for this Version, don't have need for this primitive. Rejected for that reason.

Verb: INSPECT
Source: "Telerobotic Application to EVA" MDAC 10/88
History: ORIGINAL DEFINITION (from Source):
To observe an object carefully noting status or condition (syn: examine, observe)

JPL: change to 'To examine an object carefully noting status or condition in relation to a list/set of nominal characteristics.'

KLAUS: Change definition to: 'To observe an object carefully noting status or condition 'syn: checkout)'

REAUX: OK as is.

Version 1.0 FINAL NOTES: definition modifed as suggested; this is still different from MONITOR, which deals with dynamic systems and/or processes.

Verb: INSTALL
Source: D. Klaus JSC comts on "T/R & EVA Task Anal"
History: ORIGINAL DEFINITION (from Source):
To fix in position for use.

SUGGESTED ADDITION. KEEP AS IS, CHANGE, OR LEAVE OUT.

MLD: probably needed; leave as is (almost word for word from the dictionary).

HENEGHAN: delete. If kept, the definition needs to be more precise. 'Fix' is very vague.

MLD: just as with REMOVE, we need this to deal with fasteners of all types: bolts, screws, latches, etc.

Version 1.0 FINAL NOTES: definition changed extensively to make all of the above points. Very crucial primitive.

Verb: LATCH
Source: Adv. Robotics for Veh. Proc. (Interim) JPL 5/89
History: ORIGINAL DEFINITION (from Source):
To fasten an object with a mechanism at the mating edge (e.g. a latch).
(crew) LATCH (object A)

KLAUS: no comment

REAUX: no comment

HENEGHAN: delete, covered by SECURE.

MLD: agree--covered by SECURE, if SECURE is changed as suggested. But consider: There are many types of latches, and if more than one type of fastener is included in an activity, say two latches and a pin, this verb may be needed to help differentiate

between the actions. Think about it.

HENEGHAN: ok, then why don't we also include PIN, CLIP, TETHER, etc.? I think instead of using all these verbs, we should change the syntax of SECURE to include the type of SECURing device i.e., (crew) SECURE (object A) [with (object B)]. What do you think?

Version 1.0 FINAL NOTES: deleted; covered by SECURE as revised for Version 1.0.

Verb: LOAD
Source: "Telerobotic Application to EVA" MDAC 10/88
History: ORIGINAL DEFINITION (from Source):
To place one object onto or into another.
LOAD (object A) into (object B)

JPL: As shown above, recommend deleting as a compound assemblage of other primitives. However, if the definition were changed to: 'To transfer loose material (fluid, gas, cryogens) into a container (or reservoir) through the application of pressure and/or heat.', then the syntax ' (subsystem) LOAD (consumable) into (subsystem)' would be consistent and useful.

KLAUS: Change definition to: 'Place one object to be carried onto or into another.'

REAUX: no comment

HENEGHAN: delete. covered by other verbs.

Version 1.0 FINAL NOTES: deleted as redundant.

Verb: LOOSEN
Source: Adv. Robotics for Veh. Proc. (Interim) JPL 5/89
History: ORIGINAL DEFINITION (from Source):
To rotate an object repetitively, either manually (through the EMU glove) or with a tool, in order to add play to or disengage an interface.
(crew) LOOSEN (object A) [with (object B)]

JPL: drop LOOSEN and TIGHTEN in favor of ROTATE, SECURE, RELEASE etc.

KLAUS: LOOSEN - doesn't necessarily imply "rotation". Change definition to: 'To free from restraint, make less tight.'
'Obj. A = bolt, strap, etc.'

REAUX: no comment

Version 1.0 FINAL NOTES: deleted in favor of other verbs as suggested.

Verb: LUBRICATE
Source: D. Klaus JSC comts on "T/R & EVA Task Anal"
History: ORIGINAL DEFINITION (from Source):
To apply a substance to the surface(s) of an object in order to reduce its coefficient of static and dynamic friction against another object.

SUGGESTED ADDITION. KEEP AS IS, CHANGE, OR LEAVE OUT.

Version 1.0 FINAL NOTES: incorporated as defined.

Verb: MANEUVER
Source: Adv. Robotics for Veh. Proc. (Interim) JPL 5/89
History: ORIGINAL DEFINITION (from Source):
To move an object from one position to another, either manually (EVA) or through a manipulator; condition: small (obj < 1 cu.ft.), medium (obj < 1650 lbs), large (obj >1650 lbs)

JPL: change to 'To move an object from one location to another by making a series of changes in direction or position, either manually (EVA) or through a manipulator; condition: small (obj < 1 cu.ft.), medium (obj < 1650 lbs), large (obj >1650 lbs)'

KLAUS: (Transport)

REAUX: no comment

Version 1.0 FINAL NOTES: accepted as defined, with minor suggested changes.

Verb: MATE
Source: Adv. Robotics for Veh. Proc. (Interim) JPL 5/89
History: ORIGINAL DEFINITION (from Source):
To join or fit associated parts (object A to object B); e.g., attach Velcro interface, plug in power umbilical. Condition 1: type of connection or mating (e.g., quick connect, captive pin, threaded interface, etc.); condition 2: one-handed, two-handed

JPL: change to 'To join or fit associated parts (object A to object B); e.g., MATE ORU, plug in power umbilical. Condition 1: type of connection or mating (e.g., quick connect, captive pin, threaded interface, etc.)
(syn., connect)

KLAUS: MATE - 'Connect, Attach'
(Attach Connect Latch)

REAUX: no comment

Version 1.0 FINAL NOTES: changed as suggested, emphasis on complementary connectors, esp. umbilicals (flexible objects with an end designed to interface with a panel or access port).

Verb: MEASURE
Source: "Telerobotic Application to EVA" MDAC 10/88
History: ORIGINAL DEFINITION (from Source):
To measure the physical dimension(s) of an object (syn: scale)

JPL: replace Measure' with 'To determine' and drop synonym.

KLAUS: Change definition to: To determine the physical dimension(s) of an object against a standard.

REAUX: no comment

Version 1.0 FINAL NOTES: definition changed as suggested for greater clarity.

Verb: MONITOR
Source: "Telerobotic Application to EVA" MDAC 10/88
History: ORIGINAL DEFINITION (from Source):
To detect a change in state or condition of a system (syn: observe, watch, check status)

JPL: Drop synonyms! This primitive and OBSERVE are very close but not exactly the same. MONITOR is used to mean what it says: detect change. OBSERVE requires no cognizant activity. Do we need both? If not, recommend deleting OBSERVE.

KLAUS: Change definition to: Detect a change in state or condition of a system (syn: observe)

REAUX: ok

Version 1.0 FINAL NOTES: changed definition to clarify.

Verb: OBSERVE
Source: Adv. Robotics for Veh. Proc. (Interim) JPL 5/89
History: ORIGINAL DEFINITION (from Source):
To regard with attention; to watch, especially another crewmember.
(crew) OBSERVE (object A)

JPL: Delete as redundant to MONITOR, because use of either of these primitives

implies watching for a change of state (e.g. light on, needle moved, wrench is free-floating away).

KLAUS: No comment

REAUX: delete

Version 1.0 FINAL NOTES: deleted as redundant to MONITOR, which is preferred.

Verb: OBTAIN
Source: D. Klaus JSC comts on "T/R & EVA Task Anal"
History: ORIGINAL DEFINITION (from Source):
To acquire or get.

SUGGESTED ADDITION. KEEP AS IS, CHANGE, OR LEAVE OUT.

MLD: delete - redundant to other verbs (isn't it?)

HENEGHAN: delete

Version 1.0 FINAL NOTES: deleted as redundant.

Verb: OPEN
Source: Adv. Robotics for Veh. Proc. (Interim) JPL 5/89
History: ORIGINAL DEFINITION (from Source):
To render unobstructed an entrance, opening etc. by moving an object (e.g., a door, valve or hatch).

ESTUS: add 'conduit' to definition.

KLAUS: Change definition to: To configure an object for permitting entrance or exit through a passage (or opening).

REAUX: no comment

Version 1.0 FINAL NOTES: modified to be very close to the telerobotic definition, and more precise than the original one.

Verb: PHOTOGRAPH
Source: "Telerobotic Application to EVA" MDAC 10/88
History: ORIGINAL DEFINITION (from Source):
To take still photographs of an object at a location using a hand-held camera.
(crew) PHOTOGRAPH (object) at (location)

JPL: drop this and VIDEOTAPE in favor of RECORD.

KLAUS: 'Could be addressed by "record" w/still photo.' Take still photographs of an object at a location using a hand-held camera.

REAUX: no comment

Version 1.0 FINAL NOTES: deleted as redundant to RECORD (not COMMUNICATE).

Verb: POINT
Source: "Telerobotic Application to EVA" MDAC 10/88
History: ORIGINAL DEFINITION (from Source):
To position an object in the direction of another object.
(crew) POINT (object A) toward (object B)

JPL: Delete the word POINT in favor of ALIGN, or reconcile the difference (if there is one).

REAUX: ok

KLAUS: Change POINT to 'ALIGN'

Version 1.0 FINAL NOTES: deleted as redundant to (and not as precise as) ALIGN, as defined above.

Verb: POSITION
Source: "Telerobotic Application to EVA" MDAC 10/88
History: ORIGINAL DEFINITION (from Source):
To manipulate an object into a target location.
(crew) POSITION (object) at (location)

JPL: Delete as redundant to MANEUVER and ALIGN (recommended for deletion in the Telerobotics Primitives also).

KLAUS: Change definition to: Place an object into a specific location. MANEUVER 'to move' and 'ALIGN' specific orientation

REAUX: ok

Version 1.0 FINAL NOTES: deleted as redundant to MANEUVER and ALIGN. This choice is really a matter of preference.

Verb: PROCESS
Source: "Telerobotic Application to EVA" MDAC 10/88
History: ORIGINAL DEFINITION (from Source):
To collect, arrange, comprehend, manipulate, store and recall information
PROCESS (information)

JPL: Delete - unquantifiable, and violates the definition of a primitive by its compound nature.

KLAUS: ambiguous/high level

REAUX: ok

Version 1.0 FINAL NOTES: deleted for the above reasons.

Verb: PULL
Source: M. Drews JPL comts on "T/R & EVA Task Analysis"
History: ORIGINAL DEFINITION (from Source):
To exert force on an object towards the center of the body by use of the arm(s) and hand(s) gripping the object ; implies that the astronaut is secured by a handhold and/or foothold (single foot in foot restraint).

Version 1.0 FINAL NOTES: accepted as defined.

Verb: PUSH
Source: M. Drews JPL comts on "T/R & EVA Task Anal"
History: ORIGINAL DEFINITION (from Source):
To exert force against an object away from the center of the body, usually (although not always) with the arms, but also [optionally] with another, held object, or even the feet; implies that the astronaut is secured by a handhold and/or foothold (single foot in foot restraint).

Version 1.0 FINAL NOTES: accepted as defined.

Verb: QUERY
Source: R. Reaux CTA Inc. comts on "T/R & EVA Task Anal"
History: ORIGINAL DEFINITION (from Source):
To ask or request information from a system or database.
(crew) QUERY (information) from (source)

SUGGESTED ADDITION. KEEP AS IS, CHANGE, OR LEAVE OUT.

MLD: Interesting, but is it in use? Will it be? The idea is needed, but is this the verb?

HENEGHAN: delete, covered by COMMUNICATE.

Version 1.0 FINAL NOTES: rejected

Verb: RECHARGE
Source: "Telerobotic Application to EVA" MDAC 10/88
History: ORIGINAL DEFINITION (from Source):
To re-energize a system that has been expended i.e. batteries, fuel, etc.
(crew) RECHARGE (system)

JPL: This is a placeholder for the time spent standing by while a complex activity takes place. Recommend deleting as redundant to STANDBY (and other verbs) and unnecessary.

KLAUS: Change RECHARGE: To 'configure/position system for recharge' 'Not an actual human action'

REAUX: ok

HENEGHAN: delete, unnecessary.

Version 1.0 FINAL NOTES: deleted as unnecessary.

Verb: RECORD
Source: "Telerobotic Application to EVA" MDAC 10/88
History: ORIGINAL DEFINITION (from Source):
To store information for later recall

JPL: Covered by PHOTOGRAPH and VIDEOTAPE; audio lines of communication are always open (except when switched at the discretion of the crew to avoid distraction), and no other voluntary recording capability exists. Delete as unnecessary.

KLAUS: 'RECORD' seems rather broad. There are many methods of recording (verbally, VTR, writing, photographing)

REAUX: ok

HENEGHAN: use this to cover PHOTOGRAPH, VIDEOTAPE, etc.

Version 1.0 FINAL NOTES: accepted; beefed up the definition as shown

Verb: RELEASE

Source: "Telerobotic Application to EVA" MDAC 10/88

History: ORIGINAL DEFINITION (from Source):
To disengage a mechanical interface (syn: ungrasp, demate, disconnect, ungrapple)

JPL: Replace with: 'To remove from confinement, to free from restraint; to open the snares on an enveloping end effector (such as the RMS) or a dedicated mechanism (such as a latch). Normally a preprogrammed action requiring no planning; included here as an activity that EVA crew may initiate.'

KLAUS: Change definition to: 'To unfasten and let go.

REAUX: no comment

HENEGHAN: add 'of a crewmember or a mechanical device'. This now covers the human actions of ungrasping (letting go), unlatching, etc. as well as ungrappling.

Version 1.0 FINAL NOTES: revised as suggested to allow for specification of the releasing device. This will be the first (but likely not the last) primitive to act as an antonym for two distinct but related primitives: GRAPPLE and SECURE. Only SECURE is shown as the Antonym, because it is the more general and likely to be used in EVA task breakdowns.

Verb: REMOVE

Source: "Telerobotic Application to EVA" MDAC 10/88

History: ORIGINAL DEFINITION (from Source):
To detach one object from another (i.e. cover, thermal blanket, module, etc.)

JPL: Delete as unnecessary; covered by UNCOVER, DETACH and DEMATE.

REAUX: ok

KLAUS: Replace REMOVE with 'covered by specific removal steps'
Release - maneuver, position, obtain.

MLD: changed my mind - we need this to deal with fasteners of all types: bolts, screws, latches, etc.

Version 1.0 FINAL NOTES: definition changed extensively to make all of the above points. Very crucial primitive.

Verb: REPORT
Source: D. Klaus JSC comts on "T/R & EVA Task Anal"
History: ORIGINAL DEFINITION (from Source):
To give an account of or information about an activity or process.
(crew) REPORT to (crew/system)

SUGGESTED ADDITION. KEEP AS IS, CHANGE, OR LEAVE OUT.

MLD: make more precise, re: the corresponding TelePrimitive.

HENEGHAN: delete, covered by COMMUNICATE.

Version 1.0 FINAL NOTES: rejected as unnecessary.

Verb: RESTRAIN
Source: D. Klaus JSC comts on "T/R & EVA Task Anal"
History: ORIGINAL DEFINITION (from Source):
To limit, restrict or keep under control.
(crew) RESTRAIN (object A)

SUGGESTED ADDITION. KEEP AS IS, CHANGE, OR LEAVE OUT.

MLD: what's the difference from HOLD?
Which one is more appropriate? How can they be made complementary?

HENEGHAN: use RESTRAIN as more appropriate than HOLD.

Version 1.0 FINAL NOTES: disagree with Heneghan; SECURE can do this job, but manually retaining a grasp on an object during the performance of a task calls for HOLD. That will be the primitive in this Version.

Verb: RESUME
Source: M. Drews JPL comts on "T/R & EVA Task Anal"
History: ORIGINAL DEFINITION (from Source):
To continue an operation previously halted, without having to re-initialize or restart from the beginning.

Version 1.0 FINAL NOTES: a primitive to continue activity was needed, to come conceptually after STOP. Like STOP, RESUME is suggested in this version because it is a well-understood, colloquial term that is not easily confused with another phonetically similar word.

Verb: RESUPPLY
Source: "Telerobotic Application to EVA" MDAC 10/88
History: ORIGINAL DEFINITION (from Source):
Replenish materials that were consumed (syn: refill, restock)
(crew) RESUPPLY (item)

JPL: A complex construct of various other EVA primitives, based on the type of resupply involve. Recommend deleting.

KLAUS: The word RESUPPLY - too high level

REAUX: ok

HENEGHAN: delete.

Version 1.0 FINAL NOTES: deleted as compound.

Verb: RETRACT
Source: "Telerobotic Application to EVA" MDAC 10/88
History: ORIGINAL DEFINITION (from Source):
Withdraw a subsystem from an operating configuration.
(crew) RETRACT (subsystem)

JPL: More applicable to telerobotics than EVA; not truly required here (covered by other primitives). Recommend deletion.

KLAUS: No comment

REAUX: If deleting RETRACT, should delete DEPLOY. What does EVA encompass, does that also encompass EVA operation of an RMS or is that now telerobotic?

HENEGHAN: delete

Version 1.0 FINAL NOTES: deleted by unanimous consent.

Verb: ROTATE
Source: D. Klaus JSC comts on "T/R & EVA Task Anal"
History: ORIGINAL DEFINITION (from Source):
To turn (clockwise or counterclockwise).

SUGGESTED ADDITION. KEEP AS IS, CHANGE, OR LEAVE OUT.

MLD: make more precise, re: the corresponding TelePrimitive.

HENEGHAN: change to 'To turn an object repetitively, either manually (through an EMU glove) or with a tool (e.g., in order to loosen or tighten an interface). This will then encompass many forms of rotation.

Version 1.0 FINAL NOTES: accepted with comments, because rotation is a basic motion (like translation) that must be accommodated in any number of activities.

Verb: ROUTE
Source: D. Klaus JSC comts on "T/R & EVA Task Anal"
History: ORIGINAL DEFINITION (from Source):
To transport via a specified course.

SUGGESTED ADDITION. KEEP AS IS, CHANGE, OR LEAVE OUT.

MLD: delete as unnecessary. I don't see where it would be used.

HENEGHAN: delete, not needed.

Version 1.0 FINAL NOTES: rejected as unnecessary.

Verb: SECURE
Source: Adv. Robotics for Veh. Proc. (Interim) JPL 5/89
History: ORIGINAL DEFINITION (from Source):
To fasten an object(s) for restraint (e.g., by means of a tether or latch).

REAUX: no comment.

HENEGHAN: include [with (object B)] in the syntax, so that the fastening device may be indicated.

Version 1.0 FINAL NOTES: revised as suggested to allow for specification of the securing device.

Verb: SELECT
Source: Adv. Robotics for Veh. Proc. (Interim) JPL 5/89
History: ORIGINAL DEFINITION (from Source):
To choose a preferred object from a number of options. An EVA example would be the process of choosing from a tool locker the desired tools to perform a particular task.

KLAUS: Change definition to: 'To choose a preferred object from a number of options. '

REAUX: no comment.

Version 1.0 FINAL NOTES: changed 'options' to alternatives for symantic reasons; otherwise, accepted as originally defined (approximately).

Verb: SHUTDOWN
Source: Adv. Robotics for Veh. Proc. (Interim) JPL 5/89
History: ORIGINAL DEFINITION (from Source):
To change the (sub)system state from operative to standby or inoperative. This includes system power down sequence.

KLAUS: no comment

REAUX: no comment.

HENEGHAN: no comment.

Version 1.0 FINAL NOTES: accepted as proposed; applies to ssystems and subsystems only, not the EVA crew as suggested in the comments under TERMINATE.

Verb: SOLVE
Source: "Telerobotic Application to EVA" MDAC 10/88
History: ORIGINAL DEFINITION (from Source):
To find a solution to a problem. Find an answer to a question (syn: decide)
SOLVE (problem)

JPL: Not quantifiable in EVA; ground control's function. Recommend deletion.

KLAUS: No comment

REAUX: ok

HENEGHAN: delete.

Version 1.0 FINAL NOTES: deleted as inappropriate.

Verb: STABILIZE
Source: "Telerobotic Application to EVA" MDAC 10/88
History: ORIGINAL DEFINITION (from Source):
To hold a system in a given condition

JPL: Replace with: 'To null out rates (of an object's motion) relative to some frame of reference.' The corresponding syntax would be: ' (crew) STABILIZE (object A) [vs. (frame of reference)]' Frame of reference is optional because it may be intuitive (such as with WESTAR/PALAPA - felt through the musculature of the crewperson). Better wording?

KLAUS: Change definition to, 'To hold a system in a given condition or maintain a fixed position.'

REAUX: no comment.

HENEGHAN: change to 'To dampen or eliminate motion of a system or object about one or more of its axes'.

Version 1.0 FINAL NOTES: 'system' dropped from definition; otherwise, clarified with suggested additions. No antonym is proposed, because it is difficult to conceive of a situation where one would deliberately want to DEstabilize something.

Verb: STANDBY

Source: Adv. Robotics for Veh. Proc. (Interim) JPL 5/89

History: ORIGINAL DEFINITION (from Source):
To wait, without activity, ready to resume on notification from ground control, another EVA crewperson, or onboard (IVA) control.

KLAUS: Modify definition: To wait, without activity, ready to resume on notification (from ground control, another EVA crewperson, or onboard (IVA) control).

REAUX: no comment

HENEGHAN: change to 'To wait, without activity, ready to resume on notification--from ground control, another EVA crewperson, or onboard (IVA) control'.

Version 1.0 FINAL NOTES: modified as requested.

Verb: STOP

Source: M. Drews JPL comts on "T/R & EVA Task Anal"

History: ORIGINAL DEFINITION (from Source):
To immediately halt the current activity. Usually followed by a new instruction, question, or STANDBY call.

Version 1.0 FINAL NOTES: a primitive to cease activity was needed, to come conceptually before STANDBY. TERMINATE was proposed, but STOP is suggested in this version because it is a well-understood, colloquial term that is not easily confused with another phonetically similar word.

Verb: STORE
Source: "Telerobotic Application to EVA" MDAC 10/88
History: ORIGINAL DEFINITION (from Source):
To return an object not in direct use to a storage location.
(crew) STORE (object) at (location)

JPL: Redundant to STOW, which is more common EVA terminology. Recommend deletion.

KLAUS: No comment

REAUX: ok

HENEGHAN: delete.

Version 1.0 FINAL NOTES: deleted in favor of STOW, with which this is redundant.

Verb: STOW
Source: Adv. Robotics for Veh. Proc. (Interim) JPL 5/89
History: ORIGINAL DEFINITION (from Source):
To place and secure objects in temporary or permanent storage; (condition) is either routine or nonroutine.

JPL: Routine STOW addresses handling of hardware such as foot restraints, tools, tethers, peripherals, etc, for which there is a specific storage site, and the activities involved are routine, accurately defined, and repeatable. Nonroutine STOW applies to payloads or mission-specific airborne support equipment which may have unique handling requirements and storage facilities. Times are different for each, which is the reason for the differentiation. Is this the proper way to call that out? Comments, please.

KLAUS: STOW seems rather broad and a combination of other primitives.
Change definition to: 'To place and secure objects in temporary or permanent storage in an orderly manner.
(Restrain)

REAUX: STOW in the purest sense is not a primitive. Standard STOW operations may be considered a primitive for our purposes but not nonstandard STOW operations.

HENEGHAN: delete. STOW is too high-level for this list of verbs. It can be described with other verbs, and is, therefore, unnecessary.

MLD: suggest keeping this for simple ("routine") stowing procedures; these are so learned, so practiced, that the crew knows how to do them by simply saying "stow" or

"unstow" (the wrench, the PFR, etc.). With more complicated equipment such as the MMU, or unique devices with which they may not be as familiar, a step-by-step primitive call-out might be necessary...but not always. Retain this verb, but suggest altering the syntax to read simply "(crew) STOW (object A) [in/on (location A)]".

HENEGHAN: agreed, including both object and location will usually be enough to indicate the process involved.

Version 1.0 FINAL NOTES: retained with extensive changes, to use for the reasons listed above.

Verb: TERMINATE
Source: D. Klaus JSC comts on "T/R & EVA Task Anal"
History: ORIGINAL DEFINITION (from Source):
To stop an action or operation.
(crew) TERMINATE (system)

SUGGESTED ADDITION. KEEP AS IS, CHANGE, OR LEAVE OUT.

MLD: reconcile with CLOSEOUT and the other related terms. It may be needed, or HALT, STOP, etc. might be better.

HENEGHAN: delete in favor of SHUTDOWN.

Version 1.0 FINAL NOTES: rejected in favor of STOP.

Verb: TEST
Source: "Telerobotic Application to EVA" MDAC 10/88
History: ORIGINAL DEFINITION (from Source):
To evaluate the functionality of a system. (syn: checkout)

JPL: Try this: To evaluate the physical and functional qualities of an object, subsystem or system via execution of a preprogrammed sequence (frequently, instructions from a microprocessor).

KLAUS: Probably need to have more detail than just "test."

REAUX: ok

HENEGHAN: no comment.

Version 1.0 FINAL NOTES: definition modified as suggested.

Verb: TIGHTEN

Source: Adv. Robotics for Veh. Proc. (Interim) JPL 5/89

History: ORIGINAL DEFINITION (from Source):
To rotate an object repetitively, either manually (through the EMU glove) or with a tool, in order to more firmly secure an interface.
(crew) TIGHTEN (object A) [with (object B)]

KLAUS: Delete definition. 'Tighten doesn't imply rotation, (i.e. cinch strap?) obj A - bolt, strap, etc.
To restrain or secure firmly.

REAUX: no comment

HENEGHAN: delete. This is covered by ROTATE.

Version 1.0 FINAL NOTES: deleted

Verb: TRANSFER

Source: D. Klaus JSC comts on "T/R & EVA Task Anal"

History: ORIGINAL DEFINITION (from Source):
To move an object from one location or position to another.
(crew) TRANSFER (object A)

SUGGESTED ADDITION. KEEP AS IS, CHANGE, OR LEAVE OUT.

MLD: make more precise, re: the corresponding TelePrimitive. Reconcile with TRANSPORT and HANDOFF.

HENEGHAN: delete. Covered by TRANSPORT.

Version 1.0 FINAL NOTES: rejected as unnecessary with TRANSPORT and TRANSLATE.

Verb: TRANSLATE

Source: Adv. Robotics for Veh. Proc. (Interim) JPL 5/89

History: ORIGINAL DEFINITION (from Source):
To move crew to a location by means of an object (e.g. foot and/or hand hold, slidewire), vehicle (e.g. EEU), or a telerobotic device (e.g. RMS, SSRMS, MSC).

KLAUS: Change definition to: 'To move crew to a location manually or by means of an object (e.g. (foot and) hand holds, slidewire), vehicle (e.g. EEU), or a telerobotic device (e.g. RMS, SSRMS, MSC).'

REAUX: Two totally different actions here if crew is doing the translation or is being

transported via a device such as RMS or CETF.

HENEGHAN: no comment.

Version 1.0 FINAL NOTES: definition modified as shown in line with comments above; TRANSLATE is the crew's activity.

Verb: TRANSPORT
Source: "Telerobotic Application to EVA" MDAC 10/88
History: ORIGINAL DEFINITION (from Source):
To move an object from one location to another. (syn: transfer)

JPL: Drop synonym.

KLAUS: No comment

REAUX: no comments

HENEGHAN: change to 'To move an object from one location to another by means of a crewmember or system'.

Version 1.0 FINAL NOTES: defined with changes as shown to reinforce the association with the crew as the transportation device (ie. taking the object along on executing a TRANSLATE).

Verb: UNBERTH
Source: D. Klaus JSC comts on "T/R & EVA Task Anal"
History: ORIGINAL DEFINITION (from Source):
none
SUGGESTED ADDITION. DEFINE OR LEAVE OUT.
(crew) UNBERTH (object A)

MLD: see comments on BERTH.

HENEGHAN: delete.

Version 1.0 FINAL NOTES: deleted per the same reasoning used with BERTH.

Verb: UNBOLT
Source: D. Klaus JSC comts on "T/R & EVA Task Anal"
History: ORIGINAL DEFINITION (from Source):
none
SUGGESTED ADDITION. DEFINE OR LEAVE OUT.
(crew) UNBOLT (object A) with (tool)

MLD: probably needed; make more precise, re: the corresponding TelePrimitive.

HENEGHAN: delete. see comments under 'BOLT'.

MLD: true, but don't need to tell crew that. Remember, these primitives are for people to describe discrete actions another person (albeit in a spacesuit) must take; they wouldn't go to that level of detail unless the procedure were completely unfamiliar (see note under STOW). Think the central issue is whether to call out this particular type of attachment primitive vs. saying REMOVE bolt or UNFASTEN bolt, etc. See note under LATCH. Standard crew checklist for use with tools would solve the question.

HENEGHAN: a more elaborate definition for RELEASE satisfies the above requirements.

Version 1.0 FINAL NOTES: deleted with the suggested changes to REMOVE.

Verb: UNCOVER
Source: Adv. Robotics for Veh. Proc. (Interim) JPL 5/89
History: ORIGINAL DEFINITION (from Source):
To unfasten and remove a protective envelope (e.g., micrometeor shield, MLI) from an object.
(crew) UNCOVER (object B) from (object A)

KLAUS: need details to describe ops i.e. remove (V) cover(N)

REAUX: (crew) UNCOVER (object A) from (object B)

HENEGHAN: use (covering) in the syntax.

MLD: think this primitive should be deleted for the same reasons as UNLATCH, UNBOLT, etc. - namely that it is covered (no pun intended) by the proper definition for REMOVE.

Version 1.0 FINAL NOTES: deleted with the suggested changes to REMOVE.

Verb: UNLATCH
Source: Adv. Robotics for Veh. Proc. (Interim) JPL 5/89
History: ORIGINAL DEFINITION (from Source):
To unfasten an object with a mechanism at the mating edge (e.g. a latch).
(crew) UNLATCH (object A)

KLAUS: no comment

REAUX: no comment

HENEGHAN: covered by RELEASE.

MLD: agree--covered by RELEASE, if RELEASE is changed as suggested. But consider: There are many types of latches, and if more than one type of fastener is included in an activity, say two latches and a pin, this verb may be needed to help differentiate between the actions. Think about it.

Version 1.0 FINAL NOTES: deleted with the suggested changes to RELEASE.

Verb: UNSTOW
Source: Adv. Robotics for Veh. Proc. (Interim) JPL 5/89
History: ORIGINAL DEFINITION (from Source):
To take objects from storage; (condition) is either routine or nonroutine.

JPL: Routine UNSTOW addresses handling of hardware such as foot restraints, tools, tethers, peripherals, etc, for which there is a specific storage site, and the activities involved are routine, accurately defined, and repeatable. Nonroutine UNSTOW applies to payloads or mission-specific airborne support equipment which may have unique handling requirements and storage facilities. Times are different for each, which is the reason for the differentiation. Is this the proper way to call that out? Comments, please.

KLAUS: 'UNSTOW' covered by: obtain, remove, etc.

REAUX: See comment on STOW

HENEGHAN: delete, see comment under STOW.

MLD: suggest keeping this for simple ("routine") unstowing procedures; these are so learned, so practiced, that the crew knows how to do them by simply saying "stow" or "unstow" (the wrench, the PFR, etc.). With more complicated equipment such as the MMU, or unique devices with which they may not be as familiar, a step-by-step primitive call-out might be necessary...but not always. Retain this verb, but suggest altering the syntax to read simply "(crew) STOW (object A) [in/on (location A)]".

HENEGHAN: agreed, see comment under STOW.

Version 1.0 FINAL NOTES: retained with extensive changes, to use for the reasons listed above.

Verb: VERIFY
Source: "Telerobotic Application to EVA" MDAC 10/88
History: ORIGINAL DEFINITION (from Source):

To confirm the truth or correctness of a condition

JPL: Replace with 'To confirm that a system, subsystem, or process is in an expected state or condition.'

KLAUS: Change definition to: 'Confirm the accuracy or correctness of a condition.'

REAUX: no comment

Version 1.0 FINAL NOTES: kept with beefed up definition as shown

Verb: VIDEOTAPE

Source: "Telerobotic Application to EVA" MDAC 10/88

History: ORIGINAL DEFINITION (from Source):
To record an event or scene on videotape, usually with a handheld camera (if EVA).
(crew) VIDEOTAPE (object)

KLAUS: Could be addressed by 'record' on videotape.

REAUX: no comment

HENEGHAN: delete, covered by COMMUNICATE.

MLD: agree to delete, but because it's covered by RECORD, not COMMUNICATE.

Version 1.0 FINAL NOTES: deleted as redundant.

APPENDIX C

GENERIC TELEROBOT PRIMITIVES HISTORY

Verb: ACQUIRE

Source: FTS Task Analysis Methodology 4/14/89

History: ORIGINAL DEFINITION (from Source):
To search and locate an object (target) with sensory system (syn: search)

JPL: syntax is inconsistent with the definition. Searching is unnecessary if the location can be specified. Add 'with (sensor)' as a start, drop 'at location' or define location A as a starting location. No search mechanism is specified. Ideas? Reconcile with FIND.

BOSLEY: (ACQUIRE) Misconnotes [the action of] successfully completing a search. No acquisition mechanism either. What's different from "find" or "locate?"

CREDEN: Change definition to: 'To get an object (target) located at known location A.' (May want to be more specific and include what kind of end effector or tool (i.e. grapple fixture, dexterous hand, etc.) will be used. Syntax: (subsystem) ACQUIRE (object A) at (location A) [with (end effector/tool)]

REAUX: no comment

MATIJEVIC: cannot ACQUIRE an unknown object or an object for which the model is incorrect. Does involve matching ALWAYS. May or may not involve annunciation; a tracking system would not do that.

Version 1.0 FINAL NOTES: Closeness in meaning to the other related verbs caused some difficulty. But specifying a non-contact sensor as the mechanism in the definition helps to differentiate somewhat.

Verb: ACTIVATE

Source: TEJAS M. Drews et al., JPL 1989

History: ORIGINAL DEFINITION (from Source):
To turn power on to a peripheral device attached to the wrist (e.g. an end effector, power tool, etc.)
OR
To turn-on or start-up a device or system

Antonym: DEACTIVATE

JPL: decide on the definition. The first definition IS recommended for telerobotics primitives (by JPL).

BOSLEY: I like the first, as more explicit and narrower, it that is truly what this should mean - other is very broad...

CREDEN: Use the first definition - "To turn power on to a peripheral device...". POWER takes care of the second definition. Add - Antonym: DEACTIVATE

REAUX: What is the verb then for ACTIVATING the Telerobot system if the definition is specific to peripheral device attached to a wrist.

MATIJEVIC: should refer to powering up a subsystem as well, even more so than a peripheral device; a sensing system, for example, would be activated to acquire and track, deactivated when not needed; likewise a hand controller.

Version 1.0 FINAL NOTES: changes made as suggested; reconciled with POWER as pertaining here to a subsystem (esp. an external device), there to the manipulator.

Verb: ACTUATE

Source: FTS Task Analysis Methodology 4/14/89

History: ORIGINAL DEFINITION (from Source):
To initiate an operation, to put into action (syn: operate, activate)
(system) ACTUATE (object A) (operational condition)

JPL(proposed): drop primitive altogether in favor of existing synonyms.

BOSLEY: jargon Yes

CREDEN: Agree as proposed.

REAUX: ok

Version 1.0 FINAL NOTES: deleted as unnecessary.

Verb: ADJUST

Source: FTS Task Analysis Methodology 4/14/89

History: ORIGINAL DEFINITION (from Source):
To place or return out-of-tolerance objects into a correct condition (syn: trim, tune, calibrate).

JPL: drop entirely in favor of CALIBRATE

BOSLEY: To place or return [out-of-tolerance] 'too restrictive' objects into a correct condition (syn: trim, tune [calibrate] this is more descriptive. The operation defined; an adjustment can be to a new setpoint).

CREDEN: (Proposed): Change definition - "To place or return out-of-tolerance objects to correct position or condition"
Drop synonyms CALIBRATE and TRIM
ADJUST can be done throughout a task and can be a constant process. Whereas

CALIBRATE is a one time deal and is done before a task is even started.

REAUX: ok

MATIJEVIC: agree with coments from Creden; include remarks in Def/Notes.

Version 1.0 FINAL NOTES: accepted with changes suggested by Creden.

Verb: ALIGN
Source: FTS Task Analysis Methodology 4/14/89
History: ORIGINAL DEFINITION (from Source):
To position one object into correspondence with a reference frame centered on another object's centerpoint, or to an independent reference frame.

JPL: change definition as shown, make syntax 'with (object B)' optional, as shown; alignment may be just one object to some reference frame. Also, leave 'reference frame' as the generic argument.

BOSLEY: To position one object into correspondence with a reference frame centered on another object's centerpoint, ["what attribute of? restrictive? specified point on order object?" or to an independent reference frame.

CREDEN: Agree as proposed .

REAUX: no comment

MATIJEVIC: is usually a reference frame centered on a particular feature of an object, rather than the object's centerpoint. No reference frame is truly independent, but it can be specified as to origin without identification with a particular feature if desired.

Version 1.0 FINAL NOTES: changed per comments from Matijevic.

Verb: ANALYZE
Source: VPOD Collections Set CTA Inc. 5/23/89
History: ORIGINAL DEFINITION (from Source):
To process data for information, esp. from sensors.

BOSLEY: extract information from data by applying computational rules.

CREDEN: no comment

REAUX: no comment

Version 1.0 FINAL NOTES: additional notes added for clarification of the activity normally involved in analysis.

Verb: APPROACH

Source: TEJAS M. Drews et al., JPL 1989

History: ORIGINAL DEFINITION (from Source):
To move an end effector (or vehicle) and whatever it contains, under gross motion control, from its starting point to within a TBS proximity (spherical distance) from an object.
(subsystem) APPROACH (object A)

JPL: may be unnecessary with MOVE to and MOVE until; however, may also be used for a proximity operations device (such as a robotic free flyer) - T/R community must decide which.

BOSLEY: To move an end effector (or vehicle) and whatever it contains, under gross motion control, from its starting point to a TBS proximity (spherical distance) from an object. Agree - could also be reserved to denote movement toward X along a specified vector.

CREDEN: PROPOSED : Drop the primitive in favor of MOVE until, since it includes the conditions under which it can move.

REAUX: no comment

Version 1.0 FINAL NOTES: Deleted as unnecessary in light of the MOVE primitives.

Verb: ASSEMBLE

Source: VPOD Collections Set CTA Inc. 5/23/89

History: ORIGINAL DEFINITION (from Source):
To fit together the parts of, as in assembling the parts of a planetary vehicle.
(system) ASSEMBLE (object A) to (object B)

Antonym: DISASSEMBLE

JPL: keep to use for high-level term, esp. for vehicle assembly.

BOSLEY: To fit together the parts of, as in constructing the parts of a planetary vehicle.

CREDEN: Agree as proposed

REAUX: OK

Version 1.0 FINAL NOTES: an assembly could be done any number of ways involving

one arm, two arms, an arm and a fixture, etc, and any number of discrete primitives and objects. For objects, the MOVE and ATTACH verbs do it all. For spacecraft, there is BERTH. This is a subtask, not a primitive. Deleted as compound.

Verb: ATTACH
Source: FTS Task Analysis Methodology 4/14/89
History: ORIGINAL DEFINITION (from Source):
To join one object to another, to fasten together, to make a physical connection (syn: join, fasten, connect, mate)

Antonym: DETACH

BOSLEY: To join [join does not imply that the pieces will stay together only that they are approximated] one object to another, to (fasten) [key with (mechanism 1)] together, to make a physical connection (syn: join, fasten, connect, mate)

CREDEN: PROPOSED: Drop the synonym MATE since it pertains to umbilicals only.

REAUX: no comment

MATIJEVIC: this does and should imply complementary shapes, otherwise it IS just MOVE to touch. An example of the proper use would be in seating a tool on a fastener.

Version 1.0 FINAL NOTES: disagree w. Bosley, otherwise ATTACH means only MOVE to touch; agree w. Creden & Matijevic. Additional notes added to definition to help distinguish as the 'joining' rather than the 'moving to touch'.

Verb: BERTH
Source: VPOD Collections Set CTA Inc. 5/23/89
History: ORIGINAL DEFINITION (from Source):
To place and secure, using the manipulator arm, an item on a positioning and/or retention system equipped with a fixture specifically for that purpose.

Antonym: UNBERTH

PROPOSED: replace 'item' with 'vehicle' or 'spacecraft'. Use STOW and ATTACH for objects, UNBERTH for vehicles. This is traditional usage.

BOSLEY: = holding/retaining items.

CREDEN: Agree as proposed

REAUX: no comment

Version 1.0 FINAL NOTES: removed the words 'and secure' from the definition, in order to keep the verb from being compound, and hence failing the test of a primitive as per definition. Should be OK as is, if reserved exclusively for space vehicles.

Verb: CALIBRATE

Source: VPOD Collections Set CTA Inc. 5/23/89

History: ORIGINAL DEFINITION (from Source):
To adjust a system to a performance standard.

BOSLEY: To adjust a system (its controls?) to cause system to operate according to a performance standard or specification.

CREDEN: no comment

REAUX: no comment

MATIJEVIC: should be expanded to subsystems. There are many kinds of calibration activities: to identify arm parameters; to send servoed arms/grippers to precise locations; to do database calibration, using an arm as a measuring device by resolving the arm joint configuration to the arm's base against another reference frame; camera calibration, i.e. taking measurements of the field of view containing a known object, resolving the camera parameters by counting or locating pixels. This definition should be significantly expanded to definitely cover all these possibilities.

Version 1.0 FINAL NOTES: agree with Matijevic; definition altered to incorporate many of those comments directly.

Verb: CAPTURE

Source: FTS Task Analysis Methodology 4/14/89

History: ORIGINAL DEFINITION (from Source):
To restrict or confine motion (degrees of freedom) between object and subsystem (syn: confine)

JPL: remove synonym, add the following: 'also, to close the snares on a cable-tension end effector, such as the Orbiter RMS. Antonym: RELEASE'

BOSLEY: To restrict or confine motion (degrees of freedom) between object and subsystem (syn: confine) This seems too passive to express the idea of "capture." To engage a mechanism (e.g. snares)with an object for purpose of stopping preventing its movement)

CREDEN: PROPOSED : Leave the definition as is, let GRAPPLE be the verb used with cable-tension end effectors. Antonym: RELEASE

REAUX: no comment

Version 1.0 FINAL NOTES: the secondary definition was added due to an existing, space-qualified and experienced teleoperator system (STS RMS) that has this as an action primitive for closing its snares around a grapple fixture; the snare cage is then withdrawn into the end effector through worm gears to REGIDIZE the snares, snugging the EE against the payload. Hence, GRAPPLE = CAPTURE + RIGIDIZE.

Verb: CHANGE-OUT

Source: VPOD Collections Set CTA Inc. 5/23/89

History: ORIGINAL DEFINITION (from Source):
To exchange one object for another, usu. a failed or degraded unit (such as an ORU) with a fresh unit.
(system) CHANGE-OUT (object A)

BOSLEY: [(CHANGEOUT) - I'm old-fashioned, I still like "remove/replace"] To exchange one object for another object (component) on a larger assembly of the same type, usu. a failed or degraded unit (such as an ORU) with a fresh unit.

CREDEN: PROPOSED: Keep for high level use, may be broken down into two primitives, REMOVE and INSTALL.

REAUX: no comment

Version 1.0 FINAL NOTES: a changeout of a failed object could be done any number of ways involving one arm, two arms, an arm and a fixture, etc, and any number of discrete primitives. This is a subtask, not a primitive. Deleted as compound.

Verb: CHECKOUT

Source: VPOD Collections Set CTA Inc. 5/23/89

History: ORIGINAL DEFINITION (from Source):
To perform a proceduralized test of a component's system.

JPL: change definition to "To perform a proceduralized test of a system, subsystem, or object, either of the telerobot itself or of a spacecraft on which it is working."

BOSLEY: To carry out a procedure in order to veryify/test operational capability of a component's system.

CREDEN: Agree as proposed

REAUX: no comment

Version 1.0 FINAL NOTES: emplaced the concept of 'operational readiness' in the definition.

Verb: CLEAN
Source: VPOD Collections Set CTA Inc. 5/23/89
History: ORIGINAL DEFINITION (from Source):
To remove unwanted contaminants, impurities, or objects from a surface, using an active agent (e.g a fluid, brush, etc.).
(system) CLEAN (object A) with (object B)

BOSLEY: Agents are, as it were by definition, active ... more to the point, is this condition nudging this ( ) toward the specific rather than generic??

CREDEN: no comment

REAUX: no comment

Version 1.0 FINAL NOTES: deleted as a compound activity, therefore not a primitive as defined.

Verb: CLOSE
Source: VPOD Collections Set CTA Inc. 5/23/89
History: ORIGINAL DEFINITION (from Source):
To make an enclosure inaccessible.

Antonym: OPEN

BOSLEY: To make an enclosure inaccessible 'or block throughput in a channel.'

CREDEN: no comment

REAUX: no comment

Version 1.0 FINAL NOTES: incorporated comments as shown for greater clarity in the definition.

Verb: CLOSE gripper
Source: TEJAS M. Drews et al., JPL 1989
History: ORIGINAL DEFINITION (from Source):
To move the touch pads on fingers of a multi-fingered end effector closer together.

MATIJEVIC: may also be governed by a feedback force both here and in 'OPEN gripper'.

Modify definition to conform to syntax.

Version 1.0 FINAL NOTES: CLOSE is an accepted telerobot command verb for gripper motion in many labs. The syntax below approximates the 1989 JPL Command Parser documentation (reference 10 on the contributions card). The definition follows that lead, with adjustments for Matijevic's comments.

Verb: COMPARE
Source: TEJAS M. Drews et al., JPL 1989
History: ORIGINAL DEFINITION (from Source):
To examine data so as to discover similarities or differences to an existing value or model.

BOSLEY: To examine data so as to discover similarities or differences to an existing (set of empirical) value or values derived from a model.

CREDEN: no comment

REAUX: no comment

Version 1.0 FINAL NOTES: none

Verb: COMPLY
Source: J. Matijevic JPL comts on "T/R & EVA Task Anal"
History: ORIGINAL DEFINITION (from Source):
To allow a manipulator arm to relax and react 'naturally' (kinematically as dictated by undriven joint and link properties) to forces exerted on it by another subsystem (e.g. its own end effector executing a GRASP primitive, or another manipulator moving an object to which both are grasped or grappled in unequal dual-arm operations).

Version 1.0 FINAL NOTES: this primitive replaces LIMP with a standard robotic term, and covers any modification of the control laws for a manipulator prior to a GRASP or MOVE. It is normally executed as part of either primitive when 'compliance' is specified as one of the conditions on that primitive.

Verb: COMPUTE
Source: Reqmts for EVA Robotic Assist. SWRI 10/87
History: ORIGINAL DEFINITION (from Source):
To perform a high-level cognitive process needed to reach a decision or plan.
(subsystem) COMPUTE (operation) of (datum A) and (datum B)

BOSLEY: To perform a high-level cognitive process 'to generate inormation needed to reach a decision 'only end-points ("goals")? or branch? proof in plan.

CREDEN: no comment

REAUX: To perform a high-level cognitive 'need a more suitable word than cognitive which denotes human activity' process needed to reach a decision or plan.

Version 1.0 FINAL NOTES: deleted as unnecessary; too general to be of use, actually. Computing is incorporated in most primitives as a result of built-in software or firmware executed by the effecting system or subsystem, and it does not serve a purpose as a placeholding activity.

Verb: CONFIGURE

Source: TEJAS M. Drews et al., JPL 1989

History: ORIGINAL DEFINITION (from Source):
To specify configuration of a telerobot's control system, with conditions that may include gain levels, damping ratios, a particular reference frame (such as robot-centered, tool-centered, SSLVLH or object-centered), or trajectory mode (ballistic, which implies a constant force vector, or straight newtonian) against which the control system resolves motion.

BOSLEY: To (specify configuration) - a tad circular; is specification one key concept? 'Configure - to set up for operation esp. in a particular way. (Webster)'

CREDEN: no comment

REAUX: no comment

Version 1.0 FINAL NOTES: good point from Bosley; definition changed as shown.

Verb: COUPLE

Source: VPOD Collections Set CTA Inc. 5/23/89

History: ORIGINAL DEFINITION (from Source):
To connect the two sides of automated power/data/fluid interface.

Antonym: DECOUPLE

JPL: delete entirely, using ATTACH or MATE. There are enough verbs for bringing two complementary objects together.

BOSLEY: concur

CREDEN: PROPOSED : Keep the primitive, it varies enough from MATE (umbilicals only) and ATTACH (physical/mechanical attachments).

REAUX: ok

Version 1.0 FINAL NOTES: kept for use with complementary connectors not attached to the ends of umbilicals.

Verb: CUT
Source: FTS Task Analysis Methodology 4/14/89
History: ORIGINAL DEFINITION (from Source):
To mechanically divide or to sever an object (syn: sever, separate)

JPL: drop 'separate' as a synonym; this primitive has to mean a physical rending apart of an object that is not an assembly to the telerobot; usually a tool (object B here) would be specified for the job, invoking a method.

BOSLEY: To mechanically divide or to sever an object 'or material (e.g. insulation)' (syn: sever, separate)

CREDEN: no comment

REAUX: no comment

Version 1.0 FINAL NOTES: definition expanded as shown.

Verb: DEACTIVATE
Source: TEJAS M. Drews et al., JPL 1989
History: ORIGINAL DEFINITION (from Source):
To turn power off to a peripheral device attached to the wrist (e.g. an end effector, power tool, etc.)
OR
To turn-on or start-up a device or system

Antonym: ACTIVATE

JPL: decide on the definition. The first definition IS recommended for telerobotics primitives (by JPL).

BOSLEY: See comment on Activate

CREDEN: PROPOSED (JPL): Use the first definition to correspond to ACTIVATE, POWER can take care of the second definition.

REAUX: See also comment on Activate.

MATIJEVIC: should refer to powering up a subsystem as well, even more so than a peripheral device; a sensing system, for example, would be activated to acquire and

track, deactivated when not needed; likewise a hand controller.

Version 1.0 FINAL NOTES: changes made as suggested; reconciled with POWER as pertaining here to a subsystem (esp. an external device), there to the manipulator.

Verb: DECONTAMINATE
Source: VPOD Collections Set CTA Inc. 5/23/89
History: ORIGINAL DEFINITION (from Source):
To remove unwanted microorganisms and/or contaminants using a passive system, i.e. air purification system.

JPL: This is a task-level verb, that may include many others, including INSPECT, CLEAN, VERIFY, etc. Recommend deleting it entirely as a primitive, both for that reason and because it is primarily used in reference to the IVA environment. This requires some thought and discussion. In it, remember that level should not matter as to whether a primitive verb is included, but the definition of a 'Primitive" DOES. JPL contends that this verb does not fit that definition.

BOSLEY: I agree - not a primitive per the Glossary definition.

CREDEN: Agreed as Proposed

REAUX: no comment

Version 1.0 FINAL NOTES: deleted as compound, and not a primitive as defined by the community.

Verb: DECOUPLE
Source:
History: ORIGINAL DEFINITION (from Source):
To disconnect the two sides of automated power/data/fluid interface.

Antonym: COUPLE

JPL: delete entirely, using DETACH or DEMATE. There are enough verbs for separating two complementary objects.

BOSLEY: concur

CREDEN: PROPOSED : Keep the primitive, refer to COUPLE.

REAUX: ok

Version 1.0 FINAL NOTES: Primitive retained with changes and references as shown.

Verb: DEMATE
Source: VPOD Collections Set CTA Inc. 5/23/89
History: ORIGINAL DEFINITION (from Source):
To separate an umbilical from its interface.

Antonym: MATE

NOTE: specific to umbilicals only.

BOSLEY: no comment

CREDEN: no comment

REAUX: no comment

Verb: DEPLOY
Source: FTS Task Analysis Methodology 4/14/89
History: ORIGINAL DEFINITION (from Source):
To put an object into its operational configuration by constrained motion (syn: extend)
(VPOD: To extend on automated arm or moveable structure into operational position. Opposite of RETRACT. Also to release a free-flyer or spacecraft using an RMS. Opposite of CAPTURE.)

JPL: Replace with the following definition: 'To move a mechanical appendage (e.g. a manipulator, an antenna boom, etc.) into its operational configuration. Also, to release a payload (platform or spacecraft) from its carrier spacecraft, using a manipulator or automated mechanical device.'

With RMS operations, CAPTURE and RELEASE are antonyms. DEPLOYing payloads further has been used to mean separating them from a carrier spacecraft into a free-flying state, either in their proper orbit or in a temporary orbit for later insertion into a transfer orbit by means of a mated stage (such as an IUS, or the OMV).
This is another tough one, especially for its multiple meanings and common misusage. Needs discussion. All comments are useful - make them.

BOSLEY: JPL: Replace with the following definition: 'To move a mechanical appendage (e.g. a manipulator, an antenna boom, etc.) into its operational configuration. Also, to 'separate' carrier spacecraft, using a manipulator or automated mechanical device.'

Deployment traditionally has strong connotations of "spreading out", putting into an extended mode.

CREDEN: PROPOSED : Perhaps making DEPLOY the antonym of GRAPPLE (for grapple fixture and effectors) and RELEASE/CAPTURE as opposites (for none grappled objects) and only overlap their meaning as to where to place the object to be released. Example definition - DEPLOY to move a grappled object into its operational configuration and release it. Releasing a payload from its carrier spacecraft directly does not involve telerobotics and therefore the definition should never get confused.

REAUX: suggest keeping DEPLOY only for mechanical appendages

Version 1.0 FINAL NOTES: concur with the need to keep telerobotic and spacecraft operations distinct whenever possible. Will reserve it for mechanical appendages including some types of manipulator arms; existing RMS terminology agrees with this.

Verb: DEPRESSURIZE

Source: VPOD Collections Set CTA Inc. 5/23/89

History: ORIGINAL DEFINITION (from Source):
To decrease the atmospheric pressure in an enclosed compartment, e.g. an airlock, model, node, etc.

Antonym: PRESSURIZE

JPL: delete as a telerobot verb. Is this really a function that the telerobot would perform?

BOSLEY: concur - I think in TR world the function would be to open a valve or something

CREDEN: Agree as proposed

REAUX: OK

Version 1.0 FINAL NOTES: deleted as not fitting primitives definition; this is a process, not an action for the telerobot.

Verb: DERIGIDIZE

Source: TEJAS M. Drews et al., JPL 1989

History: ORIGINAL DEFINITION (from Source):
To loosen the snares of a cable-tension end effector, such as the Orbiter RMS's, usually as part of releasing a compatible grapple fixture or object that had been snugged to that end effector.

Verb: DESIGNATE
Source: J. Matijevic JPL comts on "T/R & EVA Task Anal"
History: ORIGINAL DEFINITION (from Source):
To indicate a feature or object on a returned video scene, register (locate) it through the use of camera models, and assign a semantic label for future reference.

Version 1.0 FINAL NOTES: added as necessary given ongoing experimentation in sensing and perception labs; may be effected by an operator ('operator designate') or an automated system.

Verb: DETACH
Source: FTS Task Analysis Methodology 4/14/89
History: ORIGINAL DEFINITION (from Source):
To take apart, to unfasten, to separate one object from another (syn: disconnect, separate, unfasten, demate)

Antonym: ATTACH

BOSLEY: To take apart, to unfasten, 'closest to Webster' to separate 'this connotes "MOVE" to me...' one object from another (syn: disconnect, separate, unfasten, demate) 'This has been restricted to umbilicals = a "reserved" word??

CREDEN: PROPOSED : Drop the synonym DEMATE since it pertains to umbilicals only.

REAUX: no comment

Version 1.0 FINAL NOTES: Changes made as suggested; definition expanded to clarify meaning.

Verb: DIAGNOSE
Source: VPOD Collections Set CTA Inc. 5/23/89
History: ORIGINAL DEFINITION (from Source):
To analyze a problem and hypothesize a solution.

JPL: replace the word 'solution' with 'cause'.

BOSLEY: Yes, on every array of possible causes.

CREDEN: PROPOSED : Solution should include a cause, keep as is.

REAUX: no comment

VERSION 1.0 FINAL NOTES: final definition adapted from Random House Dictionary definition; note it is to specify a cause, not a cure.

Verb: DISASSEMBLE

Source: VPOD Collections Set CTA Inc. 5/23/89

History: ORIGINAL DEFINITION (from Source):
To separate the parts of, as in disassembling the parts of a planetary vehicle.
Antonym: ASSEMBLE
(system) DISASSEMBLE (object A) from (object B)

JPL: keep to use for high-level term, esp. for vehicle assembly.

BOSLEY: To separate the parts of, 'an integrated structure' as in disassembling the parts of a planetary vehicle.

CREDEN: Agree as proposed .

REAUX: ok

Version 1.0 FINAL NOTES: a disassembly could be done any number of ways involving one arm, two arms, an arm and a fixture, etc, and any number of discrete primitives and objects. For objects, the MOVE and DETACH verbs do it all. For spacecraft, there is UNBERTH. This is a subtask, not a primitive. Deleted as compound.

Verb: DOCK

Source: VPOD Collections Set CTA Inc. 5/23/89

History: ORIGINAL DEFINITION (from Source):
To join two free-flying vehicles in space using a docking mechanism.
Antonym: UNDOCK
(system) DOCK (vehicle) to (object A)

JPL: Delete - this is not a telerobotic primitive; for that, see BERTH and UNBERTH. The complete definition would be: 'To join two free-flying vehicles in space, usually via kinematic forces expended by the 'docking' spacecraft to propel it against a passive 'target' spacecraft and activate a docking mechanism (mechanical capture interface).' No mention of telerobots.

BOSLEY: Concur - not useful for us.

CREDEN: Agree as proposed.

REAUX: This may not be telerobotic but it is a candidate for automation.

Version 1.0 FINAL NOTES: the last comment above is important, and completely correct. However, for now, since there is no telerobot involved, it cannot by definition be a telerobotic primitive. This will be debated, it is sure, in the future, but for this version, it is deleted.

Verb: DOWNLOAD

Source: VPOD Collections Set CTA Inc. 5/23/89

History: ORIGINAL DEFINITION (from Source):
To transfer software or data from a computer system, usually from a flight computer to a ground system, or from a telerobot system to another on-orbit spacecraft, esp. the Space Station.
Antonym: UPLOAD

JPL: definition changed as shown. The main issue is: should this term be restricted in telerobotics to ground/flight data communications?

BOSLEY: No- on-oboard (e.g. SS) data system can download to TR, e.g. CAD "blueprints" or POP can download FDIR stuff..

CREDEN: PROPOSED : Is this really something that a telerobot is going to do? This is actually an action performed on the telerobot not by the telerobot. Therefore it should be deleted.

REAUX: no comment

Version 1.0 FINAL NOTES: agree with Bosley comment; also think that the TR can DOWNLOAD to another system, such as an optical disk storage device, another telerobot, or the station's data processing system. Re: comment by Creden: primitives do also include activities done without one of the telerobot's manipulators, on or using parts of the telerobot system (this includes the operator). Therefore, defined as shown.

Verb: DRAIN

Source: TEJAS M. Drews et al., JPL 1989

History: ORIGINAL DEFINITION (from Source):
To remove as much consumable (fluid, gas, cryogen) as possible from a reservoir, esp. fuel and coolant for spacecraft. Involves determining relative conditions between 'empty' and 'full', usually by means of in-place instrumentation.

Antonym: FILL

BOSLEY: Does it cause any complication to specify complete (as much as possible) drainage? - this wouldn't be necessary

CREDEN: no comment

REAUX: no comment

Version 1.0 FINAL NOTES: agree w. Bosley; does not have to be as much as possible. Ammended definition accordingly.

Verb: DUMP
Source: TEJAS M. Drews et al., JPL 1989
History: ORIGINAL DEFINITION (from Source):
To transfer all data and software in a telerobot's computing subsystem to storage, usually at a specific time.

Antonym: LOAD

BOSLEY: To 'command the (real nit-pick!!)' transfer 'of' all data and software in a telerobot's computing subsystem to storage, usually at a specific time.

CREDEN: no comment

REAUX: no comment

Version 1.0 FINAL NOTES: further clarification added as shown.

Verb: EGRESS
Source: FTS Task Analysis Methodology 4/14/89
History: ORIGINAL DEFINITION (from Source):
To go out of (syn: exit)

JPL: drop 'exit' from syntax; change to 'location A' to conform

BOSLEY: How well does this fit in TR lexicon??

CREDEN: Agree as proposed.

REAUX: no comment

Version 1.0 FINAL NOTES: cannot assume that the telerobot will not at any time be enclosed by some (un)pressurized volume, such as an airlock or hangar etc. Some space telerobots are currently specified to be able to fit through an airlock so as to simplify their own maintenance. Reserve this definition to pertain to the ENTIRE telerobot, however.

Verb: EXTEND
Source: FTS Task Analysis Methodology 4/14/89
History: ORIGINAL DEFINITION (from Source):
To make longer, to go out from system base.

Antonym: WITHDRAW

JPL: make definition 'To make longer, to move an end effector and/or an object it contains away from the telerobot system's base (object B), with no specific direction, path, or endpoint.'

BOSLEY: add 'To move an end effector or (a) segment(s) of load-bearing element of TR ("arm")'.

CREDEN: PROPOSED : "with no specific direction, path or endpoint." Is this practical, maybe an endpoint or path should be specified.

REAUX: no comment

Version 1.0 FINAL NOTES: If a specific endpoint is stated, then the proper primitive would be 'MOVE to'; if a particular path, 'MOVE along', etc. This primitive and its antonym deal with unspecified motion towards a different configuration of the manipulator, seemingly randomly. The utility is mainly as a teleoperation primitive, or a contingency move in which motion is desired immediately without planning.

Verb: EXTRACT
Source: FTS Task Analysis Methodology 4/14/89
History: ORIGINAL DEFINITION (from Source):
To pull object out of, or to remove from inside of, another object (syn: pull out)

Antonym: INSERT
Syntax: (subsystem) EXTRACT (object A) from inside (object B)

JPL: drop 'inside' from syntax and drop synonym

BOSLEY: To pull object out of, or to remove 'object/material' from inside of, another object (syn: pull out); remember, amorphous substances (e.g. fluid) can be extracted'

CREDEN: PROPOSED: Delete in favor of the new definition of REMOVE.

REAUX: no comment

Version 1.0 FINAL NOTES: the dictionary definition ('to pull or draw out, esp. by

force') is precisely this concept. Remove ('to take away or off') does not convey it by itself. Good terminology as is.

Verb: EXTRACT feature

Source: TEJAS M. Drews et al., JPL 1989

History: ORIGINAL DEFINITION (from Source):
To perform a sensing/perception algorithm that procures a 'feature' (edge or vertex) from an object.

BOSLEY: To perform a sensing/perception algorithm that procures 'what mean? What "procures" it?' a 'feature' (edge or vertex) from an object.

CREDEN: PROPOSED: Change the verb to DISTINGUISH or CHARACTERIZE.

REAUX: This seems to be a recognition process.

Version 1.0 FINAL NOTES: Feature extraction is a procedure that can be part of the object recognition process, or alternatively, part of a way to shortcut recognizing the entire object.

Verb: FILL

Source: TEJAS M. Drews et al., JPL 1989

History: ORIGINAL DEFINITION (from Source):
To put as much consumable (fluid, gas, cryogen) as possible into a reservoir, esp. fuel and coolant for spacecraft. Involves determining relative conditions between 'empty' and 'full', usually by means of in-place instrumentation.

Antonym: DRAIN

BOSLEY: To put as much consumable (fluid, gas, cryogen) as possible 'as specified; some containers specify ullage? for expansion' into a reservoir, esp. fuel and coolant for spacecraft. Involves determining relative conditions between 'empty' and 'full', usually by means of in-place instrumentation.

CREDEN: no comment

REAUX: no comment

Version 1.0 FINAL NOTES: Definition changed to indicate only the act of passing material, not the amount.

Verb: FIND

Source: TEJAS M. Drews et al., JPL 1989

History: ORIGINAL DEFINITION (from Source):
To search with sensors for an object and annunciate (to an operator or a Planning and Reasoning subsystem) when sensed; does not require identification of a previously unknown object or verification of a known object. Reconcile with ACQUIRE and LOCATE.
(subsystem) FIND (object A)

JPL: include both FIND and LOCATE, because of the differences in intent of the primitives. FIND simply searches for the presence of an object. LOCATE searches, identifies, and gives position data back to the initiating system. These primitives are important: they should be agreed to by all, if possible.

BOSLEY: I disagree that "FIND simply searches for the presence of an object." I think this way lies trouble! Try this: 'To obtain identifying information for an object and annunciate (to an operator or a Planning and Reasoning subsystem) when sensed; requires identification criteria to be stored in operator's or P&R system's memory. Reconcile with ACQUIRE.

CREDEN: PROPOSED: Keep FIND as is and go with the proposal for LOCATE

REAUX: The distinction between FIND and LOCATE, at least by definition indicates that FIND is a suboperation of LOCATE. I would delete FIND and keep LOCATE.

Version 1.0 FINAL NOTES: agree with deleting this verb as unnecessary considering ACQUIRE and LOCATE.

Verb: FOLD

Source: VPOD Collections Set CTA Inc. 5/23/89

History: ORIGINAL DEFINITION (from Source):
To bend a flexible covering (e.g. thermal blanket) into sections.

Antonym: UNFOLD

JPL: use Webster's defintion ('To bend or press (something) so that one part is over another; double up upon itself'), replacing '(something)' with "a flexible object, e.g. a thermal blanket, cable, etc.'. This would be more clear, and consistent with the syntax below. NOTE: this is an EXTREMELY complex action for a telerobot to execute with ANY degree of autonomy; for the near future, we can assume it is done teleoperatively.

BOSLEY: good! agree as proposed

CREDEN: Agree as proposed.

REAUX: no comment

Version 1.0 FINAL NOTES: changed definition as proposed in the interests of clarity.

Verb: FREEZE
Source: FTS Task Analysis Methodology 4/14/89
History: ORIGINAL DEFINITION (from Source):
To hold (maintain) sub-system's position (syn: stop)

JPL: change to 'To halt (stop) a subsystem's or system's motion by (brakes, power-off, both).'

BOSLEY: There's also "freeze-frame" in video.

CREDEN: Agree as proposed.

REAUX: no comment

Version 1.0 FINAL NOTES: there are so many good verbs to use here: freeze, halt, stop. FREEZE is already in use, and gives an impression of immediacy when employed as slang. Adding 'immediately' to the definition emphasizes this; adding the rest further clarifies it.

Verb: GRAPPLE
Source: FTS Task Analysis Methodology 4/14/89
History: ORIGINAL DEFINITION (from Source):
To attach a sub-system to an object using a grapple fixture.

Antonym: RELEASE

JPL: replace 'sub-system' with 'enclosure-type end effector (e.g. as the Orbiter RMS EE)' in the definition; also, drop 'grapple fixture implied' from syntax shown and add it as parenthetical to the definition, with the addition of the words 'but not required', since a grappling device can grapple other things in an emergency (remember Solar Max?). This primitive replaces GRASP for manipulators that DO NOT have multifingered end effectors.

BOSLEY: JPL: replace 'sub-system' with 'enclosure-type 'yes!' end effector (e.g. as the Orbiter RMS EE)' in the definition; also, drop 'grapple fixture implied' '???' from syntax shown and add it as parenthetical to the definition, with the addition of the words 'but not required', since a grappling device can grapple other things in an emergency (remember Solar Max?). This primitive replaces GRASP for manipulators that DO NOT have multifingered end effectors.

CREDEN: PROPOSED: To clarify betwen GRAPPLE and CAPTURE, change definition - "To close the snares on a cable-tension end effector."
Antonym: DEPLOY: DEPLOY
Agree to drop 'grapple fixture implied' from syntax.

REAUX: no comment

Version 1.0 FINAL NOTES: definition completely rewritten per comments. It is important to delineate the difference between this primitive and GRASP.

Verb: GRASP
Source: TEJAS M. Drews et al., JPL 1989
History: ORIGINAL DEFINITION (from Source):
To take hold of firmly with a multi-fingered (2 or more) end effector, in order to eliminate relative motion between object and gripper and capture the object with the end effector (syn: grab, grip), normally requiring extensive force-feedback and planning.

BOSLEY: To 'close' a multi-fingered (2 or more) end effector, 'upon an object with force sufficient' in order to eliminate relative motion between object and gripper and capture the object with the end effector (syn: grab, grip), [normally requiring extensive force-feedback and planning] 'conditional?'

CREDEN: no comment

REAUX: no comment

Version 1.0 FINAL NOTES: comments incorporated as shown. GRASP is specifically for multi-fingered end-effectors, unlike GRAPPLE.

Verb: GRIP
Source: FTS Task Analysis Methodology 4/14/89
History: ORIGINAL DEFINITION (from Source):
To hold fast, to eliminate relative motion between object and gripper (syn: grab, grasp)
(subsystem) GRIP (object A) (location A) (orientation)

JPL: delete this primitive in favor of the better-defined GRASP

BOSLEY: concur

CREDEN: Agree as proposed

REAUX: ok

Version 1.0 FINAL NOTES: deleted as redundant and unnecessary

Verb: HANDOVER
Source: VPOD Collections Set CTA Inc. 5/23/89
History: ORIGINAL DEFINITION (from Source):
To pass physical control from one entity or facility to another (e.g from a ground station to the space station crew).

JPL: replace with 'To pass physical control of a telerobotic system from one entity or facility to another (e.g from ground station to Space Station IVA, from IVA to EVA, from Space Station to OMV, etc.).'

BOSLEY: no comment

CREDEN: Agree as proposed

REAUX: no comment

Version 1.0 FINAL NOTES: changes made as suggested for clarity

Verb: IDENTIFY
Source: FTS Task Analysis Methodology 4/14/89
History: ORIGINAL DEFINITION (from Source):
To verify, to classify, or to recognize unique characteristics of objects (syn: perceive, discern)

JPL: a telerobot subsystem can identify either features of an object (if so programmed to distinguish them) or an object itself. Syntax shown has 'feature of' as optional. Also, note: implies object is unknown, for if known, wouldn't VERIFY be better? Some of this should be added to the definition. Needs comments, please. Also recommended to drop synonyms; they only serve to confuse here.

BOSLEY: JPL: 'IDENTIFY vs. VERIFY question is a good one! Agree with point on feature extraction. Identify carries implicit meaning of member of a uniqueness; do we need to deal here with identifying a class of objects, esp. "obstacle" regardless of specific identity.

CREDEN: PROPOSED: Change definition - "To recognize or to classify an unknown object. Use EXTRACT features (or if changed DISTINGUISH or CHARACTERIZE) to recognize specific features.
Agree to drop synonyms

REAUX: no comment

Version 1.0 FINAL NOTES: changes made to definition; retained with VERIFY.

Verb: INDEX
Source: TEJAS M. Drews et al., JPL 1989
History: ORIGINAL DEFINITION (from Source):
To designate a zero point in the relationship between a hand controller and a manipulator. This includes many types of hand controller/manipulator combinations. Dynamic reindexing is the process whereby the operator can move an end effector to a new, more comfortable position (often after a rest or after the hand controller has reached the end of its motion envelope) and start from that point as a new zero.

Version 1.0 FINAL NOTES: came up after compiled lists were distributed for comments, and is a fundamental part of manipulation, already in use.

Verb: INGRESS
Source: FTS Task Analysis Methodology 4/14/89
History: ORIGINAL DEFINITION (from Source):
to go into (syn: enter)

JPL: drop 'entrance' from syntax; change to 'location A' to conform

BOSLEY: Random thought - go into by means of an avenue provided (to differentiate from "penetrate")

CREDEN: Agree as proposed

REAUX: no comment

Version 1.0 FINAL NOTES: cannot assume that the telerobot will not at any time be enclosed by some (un)pressurized volume, such as an airlock or hangar etc. Some space telerobots are currently specified to be able to fit through an airlock so as to simplify their own maintenance. Reserve this definition to pertain to the ENTIRE telerobot, however.

Verb: INITIALIZE
Source: J. Matijevic JPL comts on "T/R & EVA Task Anal"
History: ORIGINAL DEFINITION (from Source):
To send set-up data to a subsystem; implies ACTIVATE has taken place, may require an UPLOAD if a preprogrammed sequence is not used (as is customary).

Version 1.0 FINAL NOTES: distinct from the like verbs, usually effected by sending a command to start a preprogrammed setup sequence. Common robotics parlance.

Verb: INITIATE
Source: VPOD Collections Set CTA Inc. 5/23/89
History: ORIGINAL DEFINITION (from Source):
To begin or originate an operation or procedure.
Antonym: TERMINATE

JPL: replace 'operation' with 'sequence' in the definition. The primitive verbs initiate their own operations. This verb either should be used to kick off a special sequence not covered by an existing verb, or deleted from the list altogether.

BOSLEY: good point; however, procedure strongly implies a sequence of actions, in itself

CREDEN: Agree to drop the primitive.

REAUX: no comment

Version 1.0 FINAL NOTES: kept as originally defined to serve as a starter for activities that do not start themselves.

Verb: INSERT
Source: FTS Task Analysis Methodology 4/14/89
History: ORIGINAL DEFINITION (from Source):
To place object inside of, or put into, another object (syn: put in)

Antonym: EXTRACT

JPL: drop the synonym but associate this verb with the corresponding synonym on the EVA side.

BOSLEY: See comment above on INGRESS...

CREDEN: PROPOSED: This could be the second part of CHANGE-OUT (Refer to REMOVE)

REAUX: no comment

Version 1.0 FINAL NOTES: kept as originally defined.

Verb: INSPECT
Source: Reqmts for EVA Robotic Assist. SWRI 10/87
History: ORIGINAL DEFINITION (from Source):
To determine the condition of an object when its location is known.

(VPOD: 'To visually, or with the aid of CCTV's, examine the physical condition of a component.')

JPL: replace definition with 'To non-destructively examine an object, with or without tools (sensors), to verify conformance to design.' Inspection does not always have to be visual, nor for a specific condition, nor of an object in a known location (it's up to the telerobot or controller to LOCATE and IDENTIFY an object first).

BOSLEY: good point(s)

CREDEN: Agree as proposed

REAUX: OK

Version 1.0 FINAL NOTES: the purpose of an inspection is to notice differences, either from what's expected (from a previous examination) or mandated (designed). The definition tries to convey that without mandating the means.

Verb: INSTALL
Source: VPOD Collections Set CTA Inc. 5/23/89
History: ORIGINAL DEFINITION (from Source):
To position and connect a component on a work site.
Antonym: REMOVE
(system) INSTALL (object A) on (location A)

JPL: use as written. Complex.

BOSLEY: To position and connect a 'functional unit' component on a 'designated mounting point.'

CREDEN: no comment

REAUX: no comment

Version 1.0 FINAL NOTES: this by its original definition is a compound activity... position + connect. POSITION itself was deleted (in this Version of the primitives) for those same reasons, superceded by 'MOVE to' and ORIENT. Deleted for that purpose as redundant to these two existing verbs.

Verb: LIMP
Source: FTS Task Analysis Methodology 4/14/89
History: ORIGINAL DEFINITION (from Source):
To yield or to slack a sub-system to comply with another sub-system.
(subsystem A) LIMP to comply with (sub-system B)

BOSLEY: not an active verb - unusual to use it as such. RELAX?

CREDEN: no comment

REAUX: limp in this context is not a verb

MATIJEVIC: inconsistent with standard telerobotics terminology, in which the 'relaxation' or release of control over a manipulator is simply called 'compliance. Therefore suggest COMPLY as a much more suitable verb.

Version 1.0 FINAL NOTES: deleted in favor of COMPLY.

Verb: LOAD
Source: VPOD Collections Set CTA Inc. 5/23/89
History: ORIGINAL DEFINITION (from Source):
To transfer an object onto a transport vehicle.

Antonym: OFFLOAD

JPL: changed 'into' to 'onto' as shown; add 'or container (e.g. LOAD strut onto pallet); denotes placement on a complex surface rather than within an enclosure, as with INSERT.'

BOSLEY: also need to insure contrast with FILL

CREDEN: no comment

REAUX: no comment

Version 1.0 FINAL NOTES: changes to definition implemented as suggested to add clarity and differentiate from INSERT.
'Transfer' is already a verb primitive, and as such does not fit here; this is actually a very complex MOVE activity, but retained for the purposes of planning, where it denotes adding objects to something.

Verb: LOAD subsystem
Source: TEJAS M. Drews et al., JPL 1989
History: ORIGINAL DEFINITION (from Source):
To transfer software into a telerobot 's computing subsystem to initialize it from a dormant state.
Antonym: DUMP
(system) LOAD (subsystem) with (software) from (subsystem)

BOSLEY: To transfer software into a telerobot 's computing subsystem 'when TR is in

dormat state' initialize it for a TBS operational sequence.

CREDEN: no comment

REAUX: To transfer software into a telerobot 's computing subsystem.

Version 1.0 FINAL NOTES: deleted as redundant to UPLOAD and confusing with the standard LOAD. Comments to this verb applied to UPLOAD.

Verb: LOCATE
Source: FTS Task Analysis Methodology 4/14/89
History: ORIGINAL DEFINITION (from Source):
To determine position with respect to a frame of reference (syn: find)

JPL: replace with 'To search with sensors for an object, identify it when sensed (if known and modelled or reasoned), and determine its position with respect to a frame of reference.' (note this also drops the synonym)

BOSLEY: JPL: replace with 'To search 'again, its own primitive? obtain data from sensors' with sensors for an object, [identify it when sensed (if known and modelled or reasoned),] is this absolutely necessary? work with features (edges)] and determine its position with respect to a frame of reference.' (note this also drops the synonym)

CREDEN: Agree as Proposed

REAUX: see comments on FIND

Version 1.0 FINAL NOTES: definition expanded as shown in coordination with comments on deleted verb FIND.

Verb: MATCH
Source: TEJAS M. Drews et al., JPL 1989
History: ORIGINAL DEFINITION (from Source):
To find correlation, by an unspecified algorithm, between a sensed image and an existing model in CAD or some other database

BOSLEY: To 'correlate', by a 'TBS' unspecified algorithm, 'TBS features of a sensed image and an existing model in CAD or some other database

CREDEN: no comment

REAUX: no comment

Version 1.0 FINAL NOTES: model matching is an accepted technique in machine vision.

Athough the results may be the same (match found or not found), the premise is different between MATCH and COMPARE. This verb is limited to sensed feature comparisons in machine vision, and assumes that the objective is to find similar data sets. COMPARE sets no such restrictions. Kept both for that reason.

Verb: MATE
Source: VPOD Collections Set CTA Inc. 5/23/89
History: ORIGINAL DEFINITION (from Source):
To connect an umbilical from its interface.

Antonym: DEMATE

JPL: keep, note this is specific to umbilicals only.

BOSLEY: To connect an umbilical with its interface.

CREDEN: no comment

REAUX: no comment

Version 1.0 FINAL NOTES: definition strengthened to reserve use for umbilicals.

Verb: MONITOR
Source: VPOD Collections Set CTA Inc. 5/23/89
History: ORIGINAL DEFINITION (from Source):
To watch, observe, or keep track of a system, operation, or process.

JPL: Replace 'keep track of' with 'regulate'.

BOSLEY: Good - I had same comment on EVA side

CREDEN: PROPOSED: Delete 'keep track of'. Do not add regulate, it suggests some interaction with the system.

REAUX: no comment

Version 1.0 FINAL NOTES: there being no discernable difference in intent, level, or special circumstances between this verb and OBSERVE, kept this verb due to the closer dictionary definition to the concept (watching a machine r system, with instruments etc.).

Verb: MOVE

Source: TEJAS M. Drews et al., JPL 1989

History: ORIGINAL DEFINITION (from Source):
To change the position of an object (including a part of a telerobotic system) in a straight line and in a given direction with respect to a Cartesian reference frame resolved to the base of the telerobot; no conditions are assigned, i.e. this is free motion, unguarded, unconstrained, without stopping at a certain point or in response to a certain resisting force.

BOSLEY: no comment

CREDEN: no comment

REAUX: delete 'in a straight line and in a given direction'

MATIJEVIC: needs conditions; almost no MOVE is executed anymore without them. A Cartesian reference frame is not required, nor is resolution to the telerobot base. Motion will never truly be in a straight line; the EE path is dictated by many factors.

Version 1.0 FINAL NOTES: this is the most basic, fundamental, variegated, and highly conditioned primitive in telerobotics. The division of it into similar, multiple verbs is in order to give structure to the concept behind the motion at the outset. Conditions were added on the very strong argument that there will always be a need for some conditions.

Verb: MOVE along

Source: TEJAS M. Drews et al., JPL 1989

History: ORIGINAL DEFINITION (from Source):
To change the position of an object (including a part of a telerobotic system) with respect to a reference frame resolved to the base of the telerobot, ALONG (conforming the motion to) a specified feature (path, edge, or surface) of an object being sensed, WITH conditions [optional] that are assigned to the motion from a menu that may include type of motion (guarded, constrained, gross, fine, collision avoidance, etc. or a combination).

BOSLEY: form??

CREDEN: no comment

REAUX: don't need 4 moves

MATIJEVIC: this primitive encompasses guarded moves (moves along a surface); OK as is

Version 1.0 FINAL NOTES: MOVE is the most basic, fundamental, variegated, and highly conditioned primitive in telerobotics. The division of it into similar, multiple verbs is in order to give structure to the concept behind the motion at the outset.

Verb: MOVE to

Source: TEJAS M. Drews et al., JPL 1989

History: ORIGINAL DEFINITION (from Source):
To change the position of an object (including a part of a telerobotic system) with respect to a reference frame resolved to the base of the telerobot, TO a specified location in the telerobot's reference frame (direct or translated), WITH conditions [optional] that are assigned to the motion from a menu that may include type of motion (guarded, constrained, gross, fine, etc. or a combination).
(system) MOVE (object A) to (location A/orientation) [with (conditions)]

BOSLEY: no comment

CREDEN: no comment

REAUX: delete

MATIJEVIC: delete due to revised definition for MOVE, because only one verb is required for moves not involving force/torque feedback.

Version 1.0 FINAL NOTES: deleted for the reasons stated above; MOVE definition covers this concept.

Verb: MOVE until

Source: TEJAS M. Drews et al., JPL 1989

History: ORIGINAL DEFINITION (from Source):
To change the position of an object (including a part of a telerobotic system) with respect to a reference frame resolved to the base of the telerobot, UNTIL a specified force against the telerobot's frame is sensed, WITH conditions [optional] that are assigned to the motion from a menu that may include type of motion (guarded, constrained, gross, fine, collision avoidance, etc. or a combination).

BOSLEY: or other sensor input e.g., laser ranging

CREDEN: no comment

REAUX: delete

MATIJEVIC: this primitive is for contacting an object, i.e. moving until a specified feedback force is sensed; OK as is

Version 1.0 FINAL NOTES: MOVE is the most basic, fundamental, variegated, and

highly conditioned primitive in telerobotics. The division of it into similar, multiple verbs is in order to give structure to the concept behind the motion at the outset.

Verb: MOVE while

Source: TEJAS M. Drews et al., JPL 1989

History: ORIGINAL DEFINITION (from Source):
To change the position of an object (including a part of a telerobotic system) with respect to a reference frame resolved to the base of the telerobot, WHILE a specified force against the telerobot's frame is sensed (normally to follow a surface or edge via force feedback), WITH conditions [optional] that are assigned to the motion from a menu that may include type of motion (guarded, constrained, gross, fine, collision avoidance, etc. or a combination).

BOSLEY: see prev. comment

CREDEN: no comment

REAUX: delete

MATIJEVIC: this primitive is for maintaining a specified force against an already contacted object; OK as is

Version 1.0 FINAL NOTES: MOVE is the most basic, fundamental, variegated, and highly conditioned primitive in telerobotics. The division of it into similar, multiple verbs is in order to give structure to the concept behind the motion at the outset.

Verb: OBSERVE

Source: FTS Task Analysis Methodology 4/14/89

History: ORIGINAL DEFINITION (from Source):
To provide surveillance of an action or object (syn: monitor)
(system) OBSERVE (object A) (action)

JPL: delete in favor of MONITOR.

BOSLEY: I had a little problem here on the EVA side - MONITOR is pretty strongly purposive. An OBSERVATION can be more incidental, like just get sense data period. But I'm not sure that means much!!

CREDEN: Agree as proposed

REAUX: ok

Version 1.0 FINAL NOTES: there being no discernable difference in intent, level, or special circumstances between this verb and MONITOR, deleted this verb due to a closer dictionary definition to the closer dictionary definition to the concept

(watching a machine or system, with instruments etc.) in MONITOR.

Verb: OFFLOAD
Source: VPOD Collections Set CTA Inc. 5/23/89
History: ORIGINAL DEFINITION (from Source):
To transfer an object off a transport vehicle.

Antonym: LOAD

JPL: changed 'from' to 'off' as shown; add 'or container (e.g. OFFLOAD strut onto pallet); denotes removal from a complex surface rather than from within an enclosure, as with REMOVE.' to definition.

BOSLEY: cf EXTRACT

CREDEN: Agree as proposed

REAUX: no comment

Version 1.0 FINAL NOTES: 'Transfer' is already a verb primitive, and as such does not fit here; this is actually a very complex MOVE activity, but retained for the purposes of planning, where it denotes emptying something of objects.

Verb: OPEN
Source: TEJAS M. Drews et al., JPL 1989
History: ORIGINAL DEFINITION (from Source):
To make an enclosure accessible.

Antonym: CLOSE

BOSLEY: TO make an enclosure accessible', by manipulation of a component/subassembly designed to render it inaccessible.'

CREDEN: no comment

REAUX: no comment

Version 1.0 FINAL NOTES: incorporated comments as shown for greater clarity in the definition.

Verb: OPEN gripper
Source: TEJAS M. Drews et al., JPL 1989
History: ORIGINAL DEFINITION (from Source):
To move the touch pads on fingers of a multi-fingered end effector farther apart.

MATIJEVIC: may also be governed by a feedback force both here and in 'OPEN gripper'.

Version 1.0 FINAL NOTES: OPEN is an accepted telerobot command verb for gripper motion in many labs. The syntax below approximates the 1989 JPL Command Parser documentation (reference 10 on the contributions card). The definition follows that lead, with adjustments for Matijevic's comments.

Verb: ORIENT
Source: FTS Task Analysis Methodology 4/14/89
History: ORIGINAL DEFINITION (from Source):
To rotate an object about a single axis to bring into registry with position on same axis of another object (syn: clock)
(subsystem) ORIENT (object A) to (object B)

JPL: delete synonym; this is different from ALIGN, but not much. These should be reconciled.

BOSLEY: To rotate an object about a single axis to bring into registry with 'the' position on same axis of another object (syn: clock)

CREDEN: PROPOSED: ORIENT is limited to one axis, ALIGN is much more general. Delete ORIENT in favor of the more general.

REAUX: delete

Version 1.0 FINAL NOTES: this verb IS less versatile than ALIGN, because it deals with relative positioning between two objects only, and only in one axis at a time. Deleted as unnecessary given ALIGN as it is defined.

Verb: PAN
Source: TEJAS M. Drews et al., JPL 1989
History: ORIGINAL DEFINITION (from Source):
To orient a resource (usu. a sensor, e.g. video camera, still camera, laser rangefinder, etc.) in azimuth (yaw).

BOSLEY: or SCAN [direction/path] to cover all cases of moving sensor.

CREDEN: no comment

REAUX: redunt w/ORIENT - delete

Version 1.0 FINAL NOTES: with ORIENT deleted in favor of ALIGN, this verb, common terminology with in-space cameras (such as those on the RMS) is not redundant.

Verb: PAUSE

Source: TEJAS M. Drews et al., JPL 1989

History: ORIGINAL DEFINITION (from Source):
To interrupt a sequence or procedure, while retaining any interim values generated so as to recycle the procedure from its interrupt point if RESUMEd.

Version 1.0 FINAL NOTES: with RESUME, added to the primitives to cover conditions distinct from those prompting TERMINATE and INITIATE.

Verb: POSITION

Source: FTS Task Analysis Methodology 4/14/89

History: ORIGINAL DEFINITION (from Source):
To move an object from one location to another location and orient the object at the new location (The positioner base maintains location) (syn: place, hold)
(system) POSITION (object A) at (location A) with (orientation)

JPL: delete as a compound of 'MOVE to' and ORIENT (or ALIGN).

BOSLEY: JPL: delete as a compound of MOVE to and ORIENT (or ALIGN) 'concur'

CREDEN: Agree as proposed

REAUX: no comment

Version 1.0 FINAL NOTES: deleted as a compound as noted above; this does not fit the definition of a telerobotic primitive as used in this stack.

Verb: POWER

Source: TEJAS M. Drews et al., JPL 1989

History: ORIGINAL DEFINITION (from Source):
To turn power (on/off) to a peripheral device through the operator interface, or to the manipulator itself

BOSLEY: no comment

CREDEN: no comment

REAUX: delete - redundant with activiate

Version 1.0 FINAL NOTES: reconciled with ACTIVATE as pertaining here to the manipulator, there to an external device.

Verb: PRESSURIZE
Source: TEJAS M. Drews et al., JPL 1989
History: ORIGINAL DEFINITION (from Source):
To introduce fluids into a fluid transfer umbilical after mating but prior to use for FILL or DRAIN activities.

Version 1.0 FINAL NOTES: added to primitives to complement PURGE; umbilicals must be pressurized prior to transferring fluid by them.

Verb: PURGE
Source: VPOD Collections Set CTA Inc. 5/23/89
History: ORIGINAL DEFINITION (from Source):
To flush fluids from a fluid transfer umbilical prior to demating.

BOSLEY: To 'empty' fluids from a fluid transfer umbilical prior to demating.

CREDEN: no comment

REAUX: no comment

Version 1.0 FINAL NOTES: depending on the system, purging may be a simple emptying or use a nonreactive substance (usually an inert gas) to drive residuals clear of the umbilical before demating. Additional text for additional clarity of definition.

Verb: RANGE
Source: TEJAS M. Drews et al., JPL 1989
History: ORIGINAL DEFINITION (from Source):
To determine straight-line distance from the resolution point of a telerobotic system, which may involve active or passive sensing (and) algorithms for converting range from sensor to range from resolution point (object B, usually an end effector or tool)

BOSLEY: no comment

CREDEN: no comment

REAUX: no comment

MATIJEVIC: causes some confusion with LOCATE; might be useful for doing a 'relative update" as per the testbed. Involves features too, not just objects.

Version 1.0 FINAL NOTES: changed definition to delineate from LOCATE, which is an in-use command. This deals with the computations required to determine distance between two objects OR features, one of which may or may not be connected to the

manipulator.

Verb: RELEASE
Source: FTS Task Analysis Methodology 4/14/89
History: ORIGINAL DEFINITION (from Source):
To remove from confinement, to free from restraint (syn: free)

JPL: drop synonym, add '; to open the snares on an enveloping end effector (such as the RMS) or a dedicated mechanism (such as a latch). Normally a preprogrammed action requiring no planning.'

BOSLEY: no comment

CREDEN: no comment

REAUX: no comment

Version 1.0 FINAL NOTES: definition expanded as shown to account for current use in grappling end effector ops.

Verb: REMOVE
Source: VPOD Collections Set CTA Inc. 5/23/89
History: ORIGINAL DEFINITION (from Source):
To move an object from where it currently is.

JPL: delete as unnecessary vs. the MOVE primitives.

BOSLEY: concur

CREDEN: Proposed: Let this take on the definition of EXTRACT "To pull object out of, or to remove from inside of, another object." This could be used as part of the breakdown of CHANGE-OUT.'

REAUX: no comment

Version 1.0 FINAL NOTES: the dictionary definition of REMOVE ('to take away or off') does not convey the idea by itself, whereas EXTRACT ('to pull or draw out, esp. by force') is precisely this concept. Good terminology if the MOVE verbs did not exist for this purpose, but they do. Deleted as unnecessary.

Verb: REPLENISH
Source: VPOD Collections Set CTA Inc. 5/23/89
History: ORIGINAL DEFINITION (from Source):
To restock with fresh fluids, gases, and supplies (i.e. food, LOX, H2O).

(system) REPLENISH (subsystem) with (object A)

JPL: delete - does not meet the definition for a primitive, and much too complex for Telerobot primitives.

BOSLEY: concur - very high level logistic concept.

CREDEN: Agree as proposed.

REAUX: delete

Version 1.0 FINAL NOTES: deleted as suggested; does not satisfy the definition of a primitive.

Verb: RESUME
Source: TEJAS M. Drews et al., JPL 1989
History: ORIGINAL DEFINITION (from Source):
To continue a sequence or procedure after a PAUSE, using any interim values previously generated to recycle the procedure from its interrupt point.

Version 1.0 FINAL NOTES: with PAUSE, added to the primitives to cover conditions distinct from those prompting TERMINATE and INITIATE.

Verb: RETRACT
Source: FTS Task Analysis Methodology 4/14/89
History: ORIGINAL DEFINITION (from Source):
To remove object from operational configuration by constrained motion.

Antonym: DEPLOY

JPL: Replace with: 'To remove a mechanical appendage (e.g. a manipulator, an antenna boom, etc.) from its operational configuration.'

BOSLEY: JPL: Replace with: 'To 'move' a mechanical appendage (e.g. a manipulator, an antenna boom, etc.) from its operational configuration 'into a configuration designed to mininize interference w/other opus. While appendage is dormant/inoperative.

CREDEN: Agree as proposed

REAUX: no comment

CREDEN: Agree as proposed

REAUX: no comment

Version 1.0 FINAL NOTES: see DEPLOY final notes; defined simply as an antonym to that verb.

Verb: RETRIEVE

Source: VPOD Collections Set CTA Inc. 5/23/89

History: ORIGINAL DEFINITION (from Source):
To obtain an object from another location, usually a storage enclosure.
(system) RETRIEVE (object A) [from (location A)]

JPL: delete from T/R primitives list but retain for EVA primitives.

BOSLEY: concur

CREDEN: Agree to delete as T/R primitive.

REAUX: no comment

Version 1.0 FINAL NOTES: deleted as unnecessary in light of existing motion primitives, of which it is a compound.

Verb: RIGIDIZE

Source: TEJAS M. Drews et al., JPL 1989

History: ORIGINAL DEFINITION (from Source):
To retract the snares of a cable-tension end effector, such as the Orbiter RMS's, usually after enveloping a compatible grapple fixture or object, in order to draw tight and snug the payload (to which the grapple fixture or object is attached) to that end effector. Hence, GRAPPLE = CAPTURE + RIGIDIZE.

Verb: ROTATE

Source: TEJAS M. Drews et al., JPL 1989

History: ORIGINAL DEFINITION (from Source):
To revolve an object about one or more axes in a polar coordinate system resolved to the object's centerpoint (which does not change position relative to any other reference frame); this is the polar motion primitive equivalent to the Cartesian 'MOVE to'; orientation will be three angles, usually Pitch, Yaw, and Roll.
(system) ROTATE (object A) to (orientation)

BOSLEY: ok

CREDEN: no comment

REAUX: no comment

Version 1.0 FINAL NOTES: deleted as unnecessary with the existing MOVE primitive, since this specifies a 14-member homogeneous transformation (homtran) that would cover pure rotations if desired.

Verb: SCHEDULE
Source: VPOD Collections Set CTA Inc. 5/23/89
History: ORIGINAL DEFINITION (from Source):
To plan or list the time and sequence of an operation in relation to other operations.

BOSLEY: To plan or list the time 'of occurrence' and sequence of an operation in relation to other operations. 'a series of related operations'

CREDEN: Proposed: Is this really an action a telerobot would perform. Delete primitive, more of an IVA task.

REAUX: no comment

Version 1.0 FINAL NOTES: kept as a TelePrimitive, because of the hypothesis that the operator of the telerobot is part of that telerobotics system, and that therefore his/her activities in operating that system are legitimate primitives.

Verb: SCREW
Source: FTS Task Analysis Methodology 4/14/89
History: ORIGINAL DEFINITION (from Source):
To tighten a threaded fastener (syn: thread)

JPL: drop synonym; in everyday parlance, it implies 'to put threads on', which is not synonomous.

BOSLEY: good - concur

CREDEN: Agree as proposed.

REAUX: change to FASTEN to be consistent with EVA primitive

MATIJEVIC: implies that the fastener has been ATTACHed before; should so state.

Version 1.0 FINAL NOTES: SCREW is an accepted telerobot command verb in many labs. The 1989 JPL Command Parser documentation (reference 10 on the contributions card) shows the syntax as below, obviating the need for an antonym to SCREW. The definition was modified to follow that lead, with the comments shown.

Verb: SELECT mode

Source: TEJAS M. Drews et al., JPL 1989

History: ORIGINAL DEFINITION (from Source):
To select a control mode for the telerobot, normally before beginning operations if teleoperated, sometimes during the operation if dynamically planning through Artificial Intelligence. Options on (mode) include position, pose, path, velocity, shared, force feedback, compliant, single-arm, dual-arm, combinations of the above.

Version 1.0 FINAL NOTES: kept two SELECTs distinct to avoid confusion and an extremely long definition.

Verb: SELECT resource

Source: TEJAS M. Drews et al., JPL 1989

History: ORIGINAL DEFINITION (from Source):
To select a resource for the telerobot, normally during operations, in order to enhance operator interface with the task. Options on (resource) include camera, light, sensor, communications channel, etc., and combinations of the above. This primitive is normally associated with commands sent from the operator interface, but might be encountered by an intelligent telerobot selecting its own resources for a subtask.

BOSLEY: no comment

CREDEN: no comment

REAUX: see comment in SELECT mode

Version 1.0 FINAL NOTES: kept two SELECTs distinct to avoid confusion and an extremely long definition.

Verb: SLIDE

Source: FTS Task Analysis Methodology 4/14/89

History: ORIGINAL DEFINITION (from Source):
To move an object along a surface maintaining continuous contact.
(subsystem) SLIDE (object A) along (surface) (distance) (direction)

JPL: delete as redundant to 'MOVE along'

BOSLEY: good - concur

CREDEN: Agree as proposd

REAUX: delete

Version 1.0 FINAL NOTES: deleted as proposed

Verb: SPECIFY
Source: TEJAS M. Drews et al., JPL 1989
History: ORIGINAL DEFINITION (from Source):
To identify which model (CAD, numerical, etc) to access via the telerobot computational subsystem
(subsystem) SPECIFY (model)

BOSLEY: no comment

CREDEN: no comment

REAUX: This verb doesn't seem to be a telerobot operation as much as crew operation.

Version 1.0 FINAL NOTES: deleted as imprecise and redundant with MATCH

Verb: SQUEEZE
Source: TEJAS M. Drews et al., JPL 1989
History: ORIGINAL DEFINITION (from Source):
To close the fingers of a multi-fingered (2 or more) end effector upon an already-grasped object with a specified force.

Version 1.0 FINAL NOTES: already in use as a robotic command; this is distinct from GRASP in that it necessarily comes after a grasp, and distinct from 'CLOSE gripper' in that it is force-driven, not position-driven.

Verb: STABILIZE
Source: TEJAS M. Drews et al., JPL 1989
History: ORIGINAL DEFINITION (from Source): To dampen or eliminate motion of an object about one or more of its axes.

Version 1.0 FINAL NOTES: This was originally only an EVA primitive. Yet it can serve as a placeholder for the activity of waiting for a manipulator to stop moving as it naturally dampens out. Kept with minor changes (to make it more telerobotic).

Verb: STOP
Source: TEJAS M. Drews et al., JPL 1989
History: ORIGINAL DEFINITION (from Source):
To normally halt a subsystem's or system's motion by canceling execution of a motion command upon encountering a given condition (position, force, torque, or a

combination); distinct from FREEZE, which is a contingency action.

Version 1.0 FINAL NOTES: this is an accepted telerobot command, in use in many labs.

Verb: STOW
Source: FTS Task Analysis Methodology 4/14/89
History: ORIGINAL DEFINITION (from Source):
To put object into storage (syn: secure, load)

Antonym: UNSTOW

JPL: drop synonyms; see LOAD for the difference. This is not truly a primitive to a telerobot.

BOSLEY: no comment

CREDEN: Proposed: Change definition to imply self-storage. "To return system to its docking base."
Syntax: (system) STOW (system) in (home location). (The wording on this definition is not very good but I think the idea will work.)

REAUX: no comment

Version 1.0 FINAL NOTES: agree with the idea from Creden; this is existing RMS terminology.

Verb: TERMINATE
Source: VPOD Collections Set CTA Inc. 5/23/89
History: ORIGINAL DEFINITION (from Source):
To end an operation or procedure.
Antonym: INITIATE

JPL: replace 'operation' with 'sequence' in the definition. The primitive verbs usually terminate their own operations on a preset condition. This verb should either be used to interrupt and end a special sequence not covered by an existing verb, or deleted from the list altogether. See FREEZE.

BOSLEY: Good point - how about INTERRUPT? PAUSE?

CREDEN: Proposed: If contingency verbs are to be included, then keep this one to interrupt a sequence or action. Otherwise delete the verb from the list.

REAUX: no comment

Version 1.0 FINAL NOTES: kept to serve as an ending for activities that does not end

themselves. The distinction between simply ending and 'resetting' a procedure and interrupting (with PAUSE) it is that with an interruption, the sequence or procedure can be resumed from the interrupt point. See PAUSE and RESUME.

Verb: TEST
Source: FTS Task Analysis Methodology 4/14/89
History: ORIGINAL DEFINITION (from Source):
To determine or to verify operational quality or quantity of an object or process.

JPL: delete in favor of VERIFY and INITIATE, which cover it.

BOSLEY: concur

CREDEN: Agree as proposed

REAUX: delete

Version 1.0 FINAL NOTES: INITIATE and VERIFY do not cover it; kept with the definition as shown. TEST does exist and is in use on various telerobots as a command.

Verb: TILT
Source: TEJAS M. Drews et al., JPL 1989
History: ORIGINAL DEFINITION (from Source):
To orient a resource (usu. a sensor, e.g. video camera, still camera, laser rangefinder, etc.) in elevation (pitch).

BOSLEY: With respect to? frame of ref?

CREDEN: no comment

REAUX: delete - redundant with orient

Version 1.0 FINAL NOTES: with ORIENT deleted in favor of ALIGN, this verb, common terminology with in-space cameras (such as those on the RMS) is not redundant.

Verb: TOP-OFF
Source: VPOD Collections Set CTA Inc. 5/23/89
History: ORIGINAL DEFINITION (from Source):
To replenish a fluid container to maximum capacity with fluids lost through boil-off.

JPL: delete as unnecessary with FILL; primitive should not change just to suit the circumstances that caused it to be used.

BOSLEY: concur

CREDEN: Agree as proposed

REAUX: delete

Version 1.0 FINAL NOTES: deleted for the reasons above.

Verb: TOUCH
Source: J. Matijevic JPL comts on "T/R & EVA Task
History: ORIGINAL DEFINITION (from Source):
To contact a surface with a point, esp. a tool tip or finger on a multi-fingered hand.

Version 1.0 FINAL NOTES: accepted as proposed. Currently in use in several telerobotics labs.

Verb: TRACK
Source: FTS Task Analysis Methodology 4/14/89
History: ORIGINAL DEFINITION (from Source):
To follow the path or trajectory of an object with mechanical or sensory systems (syn: follow)

JPL: replace def with: "To observe or plot the path or trajectory of an object by sensory input, including feedback from joint encoders if the object is attached to an accessible telerobotic system.'

BOSLEY: no comment

CREDEN: Agree as proposed

REAUX: no comment

Version 1.0 FINAL NOTES: definition changed slightly as shown.

Verb: TRANSFER
Source: VPOD Collections Set CTA Inc. 5/23/89
History: ORIGINAL DEFINITION (from Source):
To pump fluid or gas from one container to another.

JPL: Add the following: 'Unlike FILL, does not involve determining relative conditions between 'empty' and 'full'.'

BOSLEY: To 'enable' fluid or gas 'to flow' from one container to another.

CREDEN: Agree as proposed

REAUX: no comment

Version 1.0 FINAL NOTES: generic version of this activity, without limits; additions to definition made for clarity.

Verb: TRANSLATE
Source: TEJAS M. Drews et al., JPL 1989
History: ORIGINAL DEFINITION (from Source):
To repostion the entire telerobot. For objects moved by the action, see TRANSPORT.

BOSLEY: no coment

CREDEN: no comment

REAUX: no comment

Version 1.0 FINAL NOTES: defined as originally proposed; analogous to the same activity in EVA.

Verb: TRANSMIT
Source: VPOD Collections Set CTA Inc. 5/23/89
History: ORIGINAL DEFINITION (from Source):
To send data via electromagnetic radiation (e.g. radio waves, microwaves, etc.); may imply voice communication between teleoperator and telerobot.

JPL: retain, even with UPLOAD, DOWNLOAD, etc.

BOSLEY: no comment

CREDEN: Agree as proposed

REAUX: no comment

Version 1.0 FINAL NOTES: defined as originally proposed.

Verb: TRANSPORT
Source: FTS Task Analysis Methodology 4/14/89
History: ORIGINAL DEFINITION (from Source):
To carry an object grasped by a telerobot from one location to another location by repositioning the base of the telerobot (see TRANSLATE); to move a grasped object via translation of the telerobot, i.e. implies TRANSLATE.

BOSLEY: no comment

CREDEN: no comment

REAUX: no comment

Version 1.0 FINAL NOTES: defined as originally proposed; analogous to the same activity in EVA.

Verb: TURN
Source: FTS Task Analysis Methodology 4/14/89
History: ORIGINAL DEFINITION (from Source):
To revolve an object about one or more axes (syn: spin)
(subsystem) TURN (object A) (axes) (direction) (angle)

JPL: delete as redundant to ROTATE.

BOSLEY: Concur

CREDEN: Agree as proposed

REAUX: delete

Version 1.0 FINAL NOTES: deleted as unnecessary with the existing MOVE primitive, since this specifies a 14-member homogeneous transformation (homtran) that would cover pure rotations if desired.

Verb: UNBERTH
Source: TEJAS M. Drews et al., JPL 1989
History: ORIGINAL DEFINITION (from Source):
To release and remove, using a telerobot, a vehicle (or spacecraft) from a positioning and/or retention system equipped with a fixture specifically for that purpose.

Antonym: BERTH

JPL: Use STOW and ATTACH for objects, UNBERTH for vehicles. This is traditional usage. (VPOD used DEBERTH, but RMS procedures use UNBERTH. This is recommended for that reason.)

BOSLEY: concur

CREDEN: Agree as proposed

REAUX: no comment

Version 1.0 FINAL NOTES: removed the words 'and release' from the definition, in

order to keep the verb from being compound, and hence failing the test of a primitive as per definition. Should be OK as is, if reserved exclusively for space vehicles.

Verb: UNDOCK
Source: VPOD Collections Set CTA Inc. 5/23/89
History: ORIGINAL DEFINITION (from Source):
To separate two vehicles in space that are joined by a docking mechanism.

Antonym: DOCK

JPL: Delete - this is not a telerobotic primitive; for that, see BERTH and UNBERTH. The complete definition would be 'To separate two attached vehicles into two free-flying vehicles in space, usually via kinematic forces expended by the 'undocking' spacecraft to propel it away from a passive 'target' spacecraft after releasing a docking mechanism (mechanical capture interface).' No mention of telerobots.

BOSLEY: To separate two vehicles in space that are joined by a docking mechanism. good - out!

CREDEN: Agree as proposed

REAUX: no comment

Version 1.0 FINAL NOTES: deleted for the same reasons as DOCK

Verb: UNFOLD
Source: TEJAS M. Drews et al., JPL 1989
History: ORIGINAL DEFINITION (from Source):
To bend or pull (a flexible object, e.g. a thermal blanket, cable, etc.) so that one part previously over another is removed, exposing the covered section.

Version 1.0 FINAL NOTES: added by TEJAS to complement FOLD; definition adapted from that one.

Verb: UNGRASP
Source: TEJAS M. Drews et al., JPL 1989
History: ORIGINAL DEFINITION (from Source):
To free an object from a multi-fingered end effector (syn: release); normally requiring much less planning than GRASP.

JPL: use for multifingered end effectors only; use RELEASE for cage-type end effectors (e.g. RMS) and dedicated complementary mechanisms.

BOSLEY: no comment

CREDEN: Agree as proposed

REAUX: no comment

Version 1.0 FINAL NOTES: defined as shown

Verb: UNSCREW
Source: TEJAS M. Drews et al., JPL 1989
History: ORIGINAL DEFINITION (from Source):
To tighten a threaded fastener (syn: thread)
(subsystem) UNSCREW (object A) [(location A)] (direction)

JPL: drop synonym; in everyday parlance, it implies 'to take threads off', which is not synonomous.

BOSLEY: no comment

CREDEN: Agree as proposed

REAUX: use loosen - delete

Version 1.0 FINAL NOTES: 1989 Command Parser documentation (reference 10 on the contributions card) shows the syntax as below, obviating the need for an antonym to SCREW. Deleted for that reason.

Verb: UNSTOW
Source: FTS Task Analysis Methodology 4/14/89
History: ORIGINAL DEFINITION (from Source):
Remove an object from storage to unobstructed location (syn: UNLOAD; or DEPLOY)

Antonym: STOW

JPL: drop synonyms; see LOAD for the difference. This is not truly a primitive to a telerobot.

BOSLEY: no comment

CREDEN: Proposed: Delete primitive, with the new definition of STOW there is no need for an antonym

REAUX: no comment

Version 1.0 FINAL NOTES: accepted existing RMS terminology as defined.

Verb: UPDATE
Source: TEJAS M. Drews et al., JPL 1989
History: ORIGINAL DEFINITION (from Source):
To modify a real or computed state vector or world model with newer information received from an source outside the telerobotic system.

BOSLEY: Are sensors "outside." Do they "update."?

CREDEN: Proposed: Delete since this is really an action that would be done to a telerobot not by the telerobot.

REAUX: Need a data entry verb such as INPUT

Version 1.0 FINAL NOTES: primitives do also include activities done without one of the telerobot's manipulators, on or using parts of the telerobot system (this includes the operator).Therefore, defined as shown, distinct from UPLOAD in that this deals only with the world model or state vector, no other data.

Verb: UPLOAD
Source: TEJAS M. Drews et al., JPL 1989
History: ORIGINAL DEFINITION (from Source):
To transfer software or data from a computer system, usually from a ground computer to a flight system, or from an on-orbit spacecraft, esp. the Space Station, to a telerobot system.

Antonym: DOWNLOAD

JPL: definition changed as shown. The main issue is: should this term be restricted in telerobotics to ground/flight data communications?

BOSLEY: see download

CREDEN: Proposed: Delete (see DOWNLOAD for reason)

REAUX: no comment

Version 1.0 FINAL NOTES: defined as shown, reconciled with same logic as UPLOAD.

Verb: VERIFY
Source: VPOD Collections Set CTA Inc. 5/23/89
History: ORIGINAL DEFINITION (from Source):
To confirm that a system, subsystem, or process is in an expected state or condition.

JPL: changes as shown.

BOSLEY: does this cover command verification?

CREDEN: Agree as proposed

REAUX: no comment

Version 1.0 FINAL NOTES: Changed definition slightly to conform more to the dictionary's.

Verb: WITHDRAW
Source: FTS Task Analysis Methodology 4/14/89
History: ORIGINAL DEFINITION (from Source):
To pull back, to retract toward system base.

Antonym: EXTEND

JPL: make definition 'To pull back, to retract an end effector and/or an object it contains toward the telerobot system's base (object B), with no specific direction, path, or endpoint.'

BOSLEY: no comment

CREDEN: see EXTEND

REAUX: no comment

Version 1.0 FINAL NOTES: If a specific endpoint is stated, then the proper primitive would be 'MOVE to'; if a particular path, 'MOVE along', etc. This primitive and its antonym deal with unspecified motion towards a different configuration of the manipulator, seemingly randomly. The utility is mainly as a teleoperation primitive, or a contingency move in which motion is desired immediately without planning.